U.S. Army Corps
of Engineers

Baltimore District
Norfolk District

Final

Focused Feasibility Study Report
Project 15 - Active Remediation Projects
Former Wastewater Treatment Plant
Wallops Flight Facility Formerly Used Defense Site

Wallops Island
Virginia

Contract Number W91236-08-D-0050
Delivery Order No. 0001

May 2015

Prepared for:

U.S. ARMY CORPS OF ENGINEERS
Baltimore, Maryland
Norfolk, Virginia

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FINAL

FOCUSED FEASIBILITY STUDY REPORT
PROJECT 15 - ACTIVE REMEDIATION PROJECTS
FORMER WASTEWATER TREATMENT PLANT

WALLOPS FLIGHT FACILITY FORMERLY USED DEFENSE SITE
WALLOPS ISLAND, VIRGINIA

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LIST OF ACRONYMS AND ABBREVIATIONS

µg/kg	micrograms per kilogram
µg/L	micrograms per liter
ARAR	Applicable or Relevant and Appropriate Requirements
BAF	bioaccumulation factor
BCF	bioconcentration factor
bgs	below ground surface
BHHRA	baseline human health risk assessment
BTAG	Biological Technical Assistance Group
CENAB	U.S. Army Corps of Engineers Baltimore District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CNAS	Chincoteague Naval Air Station
COC	contaminant of concern
COPC	contaminant of potential concern
COPEC	contaminant of potential ecological concern
DDD	dichlorodiphenyldichloroethane
DDE	dichlorodiphenyldichloroethylene
DDT	dichlorodiphenyltrichloroethane
DERP	Defense Environmental Restoration Program
DoD	Department of Defense
DOT	U.S. Department of Transportation
EPC	exposure point concentration
ER	Engineer Regulation
FFS	focused feasibility study
FUDS	Formerly Used Defense Site
GSFC	Goddard Space Flight Center
HI	hazard index
HQ	hazard quotient
HTRW	hazardous, toxic, and radioactive waste
I/C/R	ignitability, reactivity, and corrosivity
IC	institutional control
ILCR	incremental lifetime cancer risk
LOAEL	lowest observed adverse effects level
LTM	long-term monitoring
LUC	land use control
MCL	maximum contaminant level

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

MEK	methyl ethyl ketone
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MIBK	methyl isobutyl ketone
MOU	Memorandum of Understanding
NASA	National Aeronautics and Space Administration
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAEL	no observed adverse effect level
O&M	operation and maintenance
OSHA	Occupational Safety & Health Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PNW	present net worth
PPE	personal protective equipment
PRG	preliminary remediation goal
PRP	potentially responsible party
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RI	remedial investigation
ROD	Record of Decision
RSL	regional screening level
SAIC	Science Applications International Corporation
SARA	Superfund Amendments and Reauthorization Act of 1986
SETAC	Society for Environmental Toxicology and Chemistry
SLERA	Screening Level Ecological Risk Assessment
SVOC	semivolatile organic compound
TBC	to be considered criteria
TCLP	toxicity characteristic leaching procedure
TCRA	time critical removal action
THQ	target hazard quotient
TMV	toxicity, mobility, or volume
TPH	total petroleum hydrocarbon
U.S.C.	United States Code
UCL	upper confidence level

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

USACE	U.S. Army Corps of Engineers
EPA	U.S. Environmental Protection Agency
USFWS	U.S. Fish and Wildlife Service
UTL	upper tolerance limit
UU/UE	unlimited use/unrestricted exposure
VAC	Virginia Administrative Code
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compound
VPA	Virginia Pollutant Abatement
VSWMR	Virginia Solid Waste Management Regulations
WESTON®	Weston Solutions, Inc.
WFF	Wallops Flight Facility
WWTP	wastewater treatment plant

1. INTRODUCTION

Weston Solutions, Inc. (WESTON®), authorized by the United States Army Corps of Engineers (USACE) Baltimore District (CENAB), performed a focused feasibility study (FFS) of the former Wastewater Treatment Plant (WWTP) (WWTP site), Wallops Flight Facility (WFF) Formerly Used Defense Site (FUDS), currently located at the National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) WFF in Accomack County, Virginia. The work was performed under CENAB Contract W91236-08-D-0050, Delivery Order 0001. The FFS evaluates remedial alternatives for potential remediation at the WWTP site.

The NASA-GSFC WFF qualifies as a USACE FUDS property pursuant to the Environmental Restoration Defense Account and the Defense Environmental Restoration Program (DERP), Chapter 160 of the Superfund Amendments and Reauthorization Act of 1986 (SARA). As part of the USACE FUDS program, the USACE Baltimore District is responsible for oversight of the USACE FUDS activities at the Former WFF-FUDS.

The FFS was completed in cooperation with the USACE, United States Environmental Protection Agency (EPA) Region 3, the Commonwealth of Virginia Department of Environmental Quality (VDEQ), and NASA in accordance with the applicable federal, state, and local guidelines as required under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Investigations conducted at the WWTP site are part of the ongoing FUDS Program to identify and remediate areas within a FUDS that contain hazardous, toxic, and radioactive waste (HTRW) and ordnance-related hazards associated with previous occupation by the Department of Defense (DoD).

The FFS was conducted in accordance with the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which is published in the Code of Federal Regulations (CFR) (40 CFR Part 300); the FUDS Program Policy, USACE Engineer Regulation (ER) 200-3-1 (May 10, 2004); and the EPA *Guidance on Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988).

1.1 PURPOSE

The purpose of the FFS was to identify, develop, and perform a detailed analysis of potential remedial alternatives that meet remedial action objectives (RAOs), so that the decision-makers have adequate information to select the most appropriate remedial alternative(s) for the WWTP site. Remedial alternatives must be protective of human health and the environment and must comply with Applicable or Relevant and Appropriate Requirements (ARARs), unless waived. An FFS follows the same steps as a feasibility study but is limited to a particular environmental medium or portion of a site.

The following major steps were involved in the development of the FFS:

- Identification of RAOs (Section 2).
- Identification of ARARs and To Be Considered criteria (TBCs) (Section 2).
- Identification of general remedial actions (Section 3).
- Identification and screening of potentially applicable remedial technologies and process options for the general response actions (Section 3).

- Development and screening of a range of remedial alternatives for the WWTP site based on combinations of the remedial technologies that were retained (Section 4).
- Performance of a detailed analysis for each of the remedial alternatives using the evaluation criteria as required by the NCP (Section 5).
- Identification of the most appropriate/viable remedial alternative(s) that meet the RAOs through a comparative analysis (Section 6).

Remedial alternatives are evaluated according to the following nine criteria specified in the NCP, 40 CFR §300.430(e)(9)(iii):

- Overall protection of human health and the environment.
- Compliance with ARARs.
- Long-term effectiveness and permanence.
- Reduction in toxicity, mobility, or volume through treatment.
- Short-term effectiveness.
- Implementability.
- Cost.
- Community acceptance.
- State acceptance.

1.2 SITE DESCRIPTION AND HISTORY

1.2.1 Installation History

The Department of the Navy acquired the land in 1942 through condemnation in order to establish the Chincoteague Naval Air Station (CNAS) as a training facility for World War II naval aviators. Prior to being developed for the CNAS, the area principally consisted of farmland and marshes. Aerial photographs indicate that by 1943, various buildings and three runways were complete. Over the years, the mission of the facility changed numerous times. The three runways were modified and extended as needed with the changing mission. This modification resulted in the construction, expansion, and occasional abandonment of numerous associated structures and roadways. On 26 January 1946, the Naval Aviation Ordnance Test Station was established. In 1958, the National Aeronautics and Space Act established NASA. Although the Navy decided to shut down the CNAS, the facility continued to operate until it was officially closed in 1959. NASA took custody of the facility on 30 June 1959, along with the Wallops Mainland area. Finalization of the transfer from the Navy did not take place until 1 December 1961. From 1959 to 1974, the area consisting of the Main Base, Wallops Island, and Wallops Mainland was known as Wallops Station. During this period, activities in the study area were conducted in support of the Civilian Space Program.

In 1975, the facility name was changed to Wallops Flight Center. Activities were expanded to include studies of ocean processes. In July 1975, NASA excessed approximately 397 acres of land along the eastern extent of the Main Base to the U.S. Fish and Wildlife Service (USFWS) to establish the Wallops Island National Wildlife Refuge. In October 1981, Wallops Flight Center was consolidated with the Goddard Space Flight Center in Maryland, and the name was officially changed to WFF. Since then, WFF has become NASA's primary facility for suborbital programs (Occu-Health, 1999; Science Applications International Corporation [SAIC], 2003).

1.2.2 Site History

The WWTP site, which includes the former WWTP constructed by the Navy in the early 1940s, is located northwest of the intersection of Runway 17-35 and the abandoned taxiway that parallels Runway 10-28 in the north-central portion of the Main Base (**Figure 1-1)**. The WWTP site consists of the former WWTP facility and the approximately 0.8-acre surrounding area. It includes mounded material identified in previous investigations as possible residual sludge piles located approximately 150 to 200 feet north of the WWTP structures. In addition, two sludge-drying beds thought to contain residual sludge materials associated with former WWTP activities are located in the eastern portion of the WWTP site. A site layout map illustrating the WWTP components is provided in **Figure 1-2**.

The WWTP site is covered with and surrounded by dense vegetative cover, including woodland underbrush and young trees. Prior to initiation of the time critical removal action (TCRA) activities in 2006 (discussed below), NASA personnel cleared trees and underbrush to gain vehicle/heavy equipment access to the WWTP site and established a temporary gravel access road in the western portion of the WWTP site.

The former WWTP consists of three abandoned cinder-block structures and a trickling filter (removed in 2006). The cinder-block structures include a control/pump house, process tanks (chlorine reaction tanks, primary and final settling tanks, and sludge digestion tank), and two sludge drying beds. Three electrical transformers were formerly located adjacent to the south side of the control/pump house. Approximately 50 feet south of these structures are two more small structures, a comminutor and a valve house. The WWTP is no longer active and the structures are currently partially degraded and overgrown with vegetation. NASA abandoned the facility upon obtaining custody of the land and has not used the WWTP for any purpose since the transfer of the facility ownership in 1959.

A preliminary potentially responsible party (PRP) analysis performed by NASA in 2001 concluded that the DoD and USACE should assume responsibility for the WWTP and the surrounding area under the FUDS program (SAIC, 2003).

1.3 PREVIOUS SITE INVESTIGATIONS

Several previous (historical) investigations have been conducted at the WWTP site. A summary of the WESTON Remedial Investigation (RI) is presented in this section, and the results of historical investigations are described in the WESTON Final RI report (WESTON, 2013). The locations of historical samples are provided in **Figure 1-3**.

1.3.1 Nature and Extent of Contamination

Soils

The following analytes were detected in WWTP site soils:

- Six volatile organic compounds (VOCs) (acetone, methyl ethyl ketone [MEK], methyl isobutyl ketone [MIBK], tetrachloroethene [PCE], toluene, and total xylenes) were detected in WWTP site soils, but no VOCs were detected at concentrations above soil screening criteria. Acetone and MEK are common laboratory contaminants.
- Six semivolatile organic compounds (SVOCs) (benzo(a)pyrene, benzo(g,h,i)perylene, bis(2-ethylhexyl)phthalate, dibenz(a,h)anthracene, di-n-butyl phthalate, and indeno(1,2,3-cd)pyrene) were detected in WWTP site soils. Two of the six SVOCs

detected in WWTP site soils (benzo(a)pyrene and dibenz(a,h)anthracene) exceeded residential direct contact screening criteria in at least one sample. No SVOC results exceeded the industrial direct contact screening levels and no SVOCs exceeded background concentrations. Thus, the SVOCs detected in WWTP site soils are likely not due to WWTP activities and are likely attributable to historical use of petroleum compounds. These petroleum compounds may have contained SVOCs.

- Four pesticides and one polychlorinated biphenyl (PCB) were detected in soil. No pesticides were detected at concentrations above screening criteria. Aroclor-1260 was detected in exceedance of the residential direct contact screening level of 220 micrograms per kilogram (µg/kg) in one soil sample and in its field and blind duplicate samples at concentrations ranging from 190 µg/kg to 290 µg/kg. No results exceeded the industrial direct contact screening level.
- More than 21 metals and cyanide were detected in the WWTP site soil. However, only 7 metals (aluminum, antimony, arsenic, cobalt, iron, lead, and manganese) were detected at concentrations in exceedance of residential direct contact screening levels. Arsenic was also detected at concentrations exceeding the industrial direct contact screening level. Although background concentrations were not selected as the screening criteria, results were compared to background. Only lead was detected (in one location) at concentrations above background.

Groundwater

The following analytes were detected in WWTP site groundwater:

- Two common laboratory contaminants, acetone and MEK, were detected in the groundwater samples. Analytical results indicated that neither VOC exceeded screening levels. The presence of acetone and MEK in the samples may be attributable to laboratory contamination. PCE was also detected at a concentration of 4.4 micrograms per liter (µg/L) in groundwater collected from the upgradient monitoring well MW1. This concentration exceeds the tapwater Regional Screening Level (RSL) of 0.11 µg/L but is lower than the Maximum Contaminant Level (MCL) of 5 µg/L. PCE was detected at low levels in groundwater at upgradient well MW1; thus, its presence at this location may be attributable to migration from an unknown upgradient source.
- Five SVOCs, 2,4-dimethylphenol, 3- and 4-methylphenol, bis(2-ethylhexyl)phthalate, diethyl phthalate, and phenol, were detected in at least one groundwater sample. These SVOCs, with the exception of bis(2-ethylhexyl)phthalate, were not detected in soil and sludge at the WWTP site; thus, SVOCs in groundwater are not attributable to leaching from soil. Phthalate esters are commonly used in laboratories, and these detections may be attributable to laboratory contamination. No SVOCs were detected at concentrations exceeding their respective screening levels.
- No pesticides were detected in groundwater.
- No PCBs were detected in groundwater.
- Numerous total metals, including aluminum, arsenic, barium, calcium, chromium, cobalt, iron, magnesium, manganese, potassium, sodium, and vanadium, were detected in groundwater at the WWTP site. Only concentrations of arsenic and manganese exceeded screening criteria. Arsenic was detected at 0.01 milligrams per

liter (mg/L) at MW5 (downgradient of the former WWTP structures) and in the investigative, field duplicate, and blind duplicate samples collected from MW3 (adjacent to the former trickling filter) at concentrations ranging from 0.011 to 0.015 mg/L. The tapwater RSL for arsenic is 0.000045 mg/L. The MCL for arsenic is 0.01 mg/L. The background range of arsenic in groundwater is 0.0036 to 0.0177 mg/L as obtained from the *NASA Wallops Flight Facility Report for the Main Base* (TetraTech, 2004, Table 4.6). The arsenic concentrations detected in WWTP site monitoring wells are within the background range for WFF.

Surface Water

The following analytes were detected in WWTP site surface water:

- One VOC, chloromethane, was detected in the surface water at an estimated concentration of 0.53 µg/L. A surface water screening level is not available for chloromethane. Chloromethane was not detected in any other media at the WWTP site.
- No SVOCs were detected in surface water.
- No pesticides were detected in surface water.
- No PCBs were detected in surface water.
- Numerous metals, including aluminum, barium, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, and vanadium, were detected in the surface water sample. Aluminum, barium, iron, and manganese were detected at concentrations exceeding surface water screening levels. Metals concentrations in surface water may be associated with the migration of sediment-laden stormwater from various areas of WFF that were discharged via stormwater outfalls to the intermittent stream.

Sediment

The following analytes were detected in WWTP site sediment:

- Two common laboratory contaminants, acetone and MEK, were detected in the sediment samples. Analytical results indicated that neither VOC was detected at concentrations that exceeded screening levels for sediment. The presence of acetone and MEK in the samples may be attributable to laboratory contamination.
- No SVOCs were detected in sediment.
- Three pesticides (4,4'- dichlorodiphenyldichloroethane [DDD]; 4,4'-dichlorodiphenyldichloroethylene [DDE]; and 4,4'- dichlorodiphenyltrichloroethane [DDT]) were detected in the sediment samples. 4,4’-DDD was detected at concentrations of 2.7 µg/kg in one sample; 4,4’-DDE was detected at concentrations ranging from 1.8 to 2.6 µg/kg; and 4,4’-DDT was detected at concentrations ranging from 0.77 to 1.6 µg/kg. These pesticides were not detected at concentrations exceeding human health or ecological-based screening levels.
- No PCBs were detected in sediment.
- A total of 18 metals were detected in the sediment samples, with all but one of the maximum concentrations detected in SD2. Of these 18 metals, only one, arsenic, was detected at concentrations exceeding residential direct contact screening levels. No

metals were detected in sediment samples at concentrations exceeding ecological-based screening levels. Currently, no human-health based screening levels exist for sediment exposure; therefore, the concentrations were compared to soil screening levels. Arsenic was detected in both sediment samples at concentrations ranging from 1.4 milligrams per kilogram (mg/kg) to 2.7 mg/kg, exceeding the residential direct contact soil screening level of 0.39 mg/kg. The presence of arsenic in sediment adjacent to the WWTP site is likely a result of transport via stormwater runoff. Arsenic was detected in WWTP site soil samples at concentrations ranging from 0.76 mg/kg to 5.4 mg/kg, which is within the background range (0.78 to 14.2 mg/kg) of arsenic in surface soils as obtained from the *NASA Wallops Flight Facility Report for the Main Base* (TetraTech, 2004, Table 4.24). Sources of arsenic were not identified at the WWTP site; thus, the presence of arsenic in WWTP site soils is attributable to background conditions. The presence of arsenic in sediment adjacent to the WWTP site is also likely a result of the background concentrations of arsenic in soil that discharges to the intermittent tributary via stormwater runoff.

Sludge

The following analytes were detected in WWTP site sludges:

- Seven VOCs, 1,1,2,2-tetrachloroethane, 2-hexanone, acetone, MEK, MIBK, PCE, and toluene, were detected in the sludge samples. In general, the maximum number of VOC analytes detected and the highest concentrations were observed in the sludge sample collected from the primary settling tank (SL01). Analytical results indicated that none of the detected VOCs exceeded the residential direct contact screening levels. Acetone and MEK are common laboratory contaminants and were detected in the sludge samples at low concentrations that may be attributable to laboratory contamination. PCE was detected in only one of the three sludge samples at SL02 at a concentration of 5.1 µg/kg, below the residential direct contact screening level of 38,000 µg/kg. PCE in soil is limited to the soil and sludge within the sludge drying bed. Toluene was detected in two of the sludge samples at concentrations of 6.2 µg/kg at SL02 and 1,200 µg/kg at SL01. These concentrations did not exceed the residential direct contact soil screening level of 500,000 µg/kg.

- Seventeen SVOCs were detected in the sludge samples. The maximum SVOC concentrations were detected in the sludge sample collected from the primary settling tank (SL01). Of the 17 detected SVOCs, 6 polycyclic aromatic hydrocarbon (PAHs), benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene, were detected at concentrations exceeding their respective residential direct contact screening levels. PAH concentrations in sludge at the WWTP site are higher than the background concentrations detected in soil at WFF as presented in the *NASA Wallops Flight Facility Report for the Main Base* (TetraTech, 2004). The extent of PAH contamination is limited to the sludge within the sludge drying beds and primary settling tank. The sludge drying bed samples were composite samples collected from 0 to 2 feet below ground surface (bgs). The depth of the sludge was observed to be approximately 6 inches and was underlain by approximately 18 inches of gravel and rock that, in turn, overlie what appears to be native soil (WESTON, 2013). The presence of PAHs in the walled settling tank and sludge drying beds is thought to be attributable to the treatment of industrial water received via sanitary sewers at the WWTP and not a result of background conditions.

- Four pesticides (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, and dieldrin) were detected in the sludge samples. Three of the pesticides (4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) were detected in all of the sludge samples, with the maximum concentrations detected in the two sludge drying bed samples. Dieldrin was detected in the two sludge drying bed samples only. 4,4'-DDD was detected at concentrations ranging from 110 to 1,200 µg /kg; 4,4'-DDE was detected at concentrations ranging from 67 to 1,400 µg/kg; 4,4'-DDT was detected at concentrations ranging from 110 to 1,100 µg/kg; and dieldrin was detected at concentrations ranging from 5.6 to 9.9 µg/kg. No pesticides were detected in the sludge samples at concentrations exceeding residential direct contact screening levels.
- No PCBs were detected in the sludge samples.
- Numerous metals were detected in the three sludge samples collected from the sludge drying beds and settling tank at the WWTP site. Eight metals, including antimony, arsenic, cobalt, iron, lead, manganese, mercury, and silver, were detected at concentrations exceeding residential direct contact screening levels. Arsenic and mercury were also detected at concentrations exceeding industrial direct contact screening levels. In general, the maximum concentrations of metals were detected in the sludge samples collected from the sludge drying beds, SL02 and SL03. The concentration ranges of metals, along with a comparison to background concentrations as presented in the *NASA Wallops Flight Facility Report for the Main Base* (TetraTech, 2004, Table 4.24), are described as follows:
  - Arsenic was detected in the two samples collected from the sludge drying beds at concentrations ranging from 2.6 to 3.2 mg/kg. Results from both samples exceeded the residential direct contact screening level of 0.39 mg/kg and the industrial direct contact screening level of 1.6 mg/kg. However, arsenic concentrations were within the background range of 0.78 to 14.2 mg/kg in soils.
  - Cobalt was detected in the two samples collected from the sludge drying beds at concentrations ranging from 2.0 to 2.6 mg/kg. Results from one of the samples exceeded the residential direct contact screening level of 2.3 mg/kg. The background range of cobalt is 0.35 to 7.3 mg/kg in soils.
  - Iron was detected in all sludge samples at concentrations ranging from 12,000 to 15,000 mg/kg. Concentrations of iron exceeded the residential direct contact screening level of 5,500 mg/kg in all sludge samples. The background range of iron is 1,740 to 10,900 mg/kg in soils. Iron detected in the sludge samples exceeded the background range.
  - Lead was detected in all sludge samples at concentrations ranging from 130 to 530 mg/kg. Results from one of the samples collected from the sludge drying beds exceeded the residential direct contact screening level of 400 mg/kg. The background range of lead is 4.9 to 124 mg/kg in soils. Lead detected in the sludge samples exceeded the background range, with one sample exceeding the residential soil screening level.

- Manganese was detected in all sludge samples at concentrations ranging from 160 to 270 mg/kg. Results from two of the samples exceeded the residential direct contact screening level of 180 mg/kg. The background range of manganese is 8.4 to 781 mg/kg in soils; therefore, concentrations of manganese are within the background range.
- Mercury was detected in all sludge samples at concentrations ranging from 0.17 to 28 mg/kg. The two sludge samples collected from the sludge drying beds contained mercury concentrations exceeding the residential direct contact screening level of 0.67 mg/kg and the industrial direct contact screening level of 2.8 mg/kg. The background range of mercury is 0.025 to 0.25 mg/kg in soils. Mercury concentrations in sludge exceeded the background soil range.
- Silver was detected in the two samples collected from the sludge drying beds at concentrations ranging from 110 to 130 mg/kg. Results from both samples exceeded the residential direct contact screening level of 39 mg/kg. The background range of silver is 0.15 to 0.3 mg/kg in soils. Silver concentrations in sludge exceeded the background soil range.
- Concentrations of arsenic, cobalt, and manganese in WWTP site sludge are attributable to background concentrations in soil at the WWTP site. Concentrations of iron, lead, mercury, and silver in sludge exceeded the background range and the respective residential screening levels. The source of mercury is likely a result of residual concentrations from contact with the trickling filter. Sludge contaminants, including iron, lead, mercury, and silver, are confined to areas of the WWTP site where sludge is located.

Wastewater

The following analytes were detected in WWTP site wastewater:

- Two common laboratory contaminants, acetone and MEK, were detected in the wastewater sample collected from the primary settling tank. Analytical results indicated that neither VOC was detected at concentrations that exceeded screening levels for wastewater. The presence of acetone and MEK in the samples may be attributable to laboratory contamination.
- Three PAH constituents (fluoranthene, phenanthrene, and pyrene) were detected in the wastewater sample collected from the primary settling tank. All of the SVOCs were detected at concentrations exceeding their respective screening levels. Very little wastewater was observed at the settling tank location. The settling tank is not covered and is open to the outside. As a result, the tank continues to receive rainwater and material from outside the settling tank.
- No pesticides were detected in the wastewater samples.
- No PCBs were detected in the wastewater samples.
- Twelve metals were detected in the wastewater sample collected from the settling tank at the WWTP site. Aluminum, barium, iron, lead, and manganese were detected at concentrations exceeding surface water screening levels. The presence of metals in the water collected from the settling tank is likely a result of suspended particles

present in the sample. Aluminum, barium, iron, lead, and manganese were also detected in the sludge sample collected from the settling tank.

1.3.2 Human Health Risk Assessment

The Baseline Human Health Risk Assessment (BHHRA) was performed as part of the RI (WESTON, 2013) to assess the potential human health impacts at the WWTP site considering both the current and future uses at the WFF. The objectives of the BHHRA were to estimate potential risk to people contacting site-related contaminants of potential concern (COPCs) under scenarios of current and plausible future land uses. The BHHRA provides an analysis of risks and helps to determine the need for remedial action(s) at the WWTP site and to identify specific media and areas associated with unacceptable risk, as applicable.

1.3.2.1 Exposure Scenarios

The following exposure scenarios were identified for assessment at the WWTP site:

- Current/future adolescent child trespasser.
- Future commercial/industrial worker.
- Future construction workers.
- Hypothetical future child and adult residents.

1.3.2.2 Risk Characterization Results

The results of the risk characterization are presented as follows:

- The risk estimates for the hypothetical future residents exceeded the high end of the EPA risk management range of 1E-04 to 1E-06 cancer risk with incremental lifetime cancer risks (ILCRs) of 4E-04 for the age-adjusted adult and 3E-04 for the future adult resident.
- The risk estimates for the current/future adolescent child trespasser, future commercial/industrial worker, and future construction worker were all within the EPA risk management range of 1E-04 to 1E-06 with ILCRs of 9E-07, 8E-06, and 8E-07, respectively.
- The future adult and child resident scenarios had hazard indices (HIs) greater than the noncancer HI management level of 1 with HIs of 3 and 8, respectively. HIs were dominated by groundwater ingestion in the future child and adult residents and soil ingestion for the future child resident.
- The current/future adolescent child trespasser, future commercial/industrial worker, and future construction worker scenarios had HIs that did not exceed the noncancer HI management level of 1 with HIs of 0.02, 0.4, and 1, respectively.

1.3.2.3 Baseline Human Health Risk Assessment Summary

In summary, two exposure scenarios, the hypothetical future child and adult residents, exceeded the high end of the EPA risk management range of 1E-04 to 1E-06 cancer risk, whereas the risk estimates for the current/future adolescent child trespasser, future commercial/industrial worker, and future construction worker were all within the EPA risk management range of 1E-04 to 1E-06. The future adult and child resident scenarios had HIs greater than the noncancer HI management level of 1. HIs were dominated by groundwater ingestion in the future child and adult residents and, to a lesser extent, soil ingestion for all other HI exceedances. The future residential scenarios were included in the evaluation and established upper bound site risks and HIs for the WWTP site. However, this land/water use is not likely and does not pose a reasonable estimate of WWTP site risk. The human health risks from exposure to residual sludge were not evaluated for the hypothetical residential scenario due to the small amount of sludge present and the construction activities associated with the hypothetical scenario. In the scenario where the WWTP site is redeveloped for residential use, it was assumed that the existing WWTP structures, including residual sludge, would be removed from the site during development.

Contaminants of concern (COCs) that were determined for the WWTP site and their potential impact on WWTP site risk were as follows:

- Arsenic in soil—Arsenic is a COC for soil for the future industrial worker, age-adjusted, and adult resident based on cancer risk estimates in excess of 1E-06. However, the WWTP site ranges and averages for arsenic were within the background range. Therefore, it appears arsenic risk is a function of natural levels in the soil.
- Arsenic in groundwater—Arsenic is a COC for groundwater for the age-adjusted, child, and adult resident scenarios. Arsenic risks slightly exceeded 1E-04 for the age-adjusted and adult residents. The arsenic hazard quotient (HQ) for the child resident was 3. All arsenic levels were within the background groundwater range. Arsenic was detected at only two of the seven wells, with concentrations ranging from 10 µg/L at MW5 (downgradient of the former WWTP structures) to 15 µg/L in the blind duplicate sample, MW20, at MW3 (former trickling filter location). Background arsenic concentrations range from 3.6 µg/L to 17.7 µg/L. Therefore, it appears arsenic risk is a function of natural levels in the groundwater.
- Benzo(a)pyrene in sludge—Benzo(a)pyrene is a COC for sludge for the future industrial worker based on a cancer risk estimate in excess of 1E-06. Risk through incidental sludge ingestion and dermal contact with sludge were both at 1E-06. Given the conservatism of the assumptions for sludge exposure, the risks are not likely to be of concern and are within the management range of 1E-06 to 1E-04.
- PCE in groundwater—PCE is a COC for groundwater for the age-adjusted and adult resident scenarios. PCE posed risks in excess of 1E-05 through tap water ingestion and dermal contact while showering/bathing in a hypothetical residential exposure scenario. Risks for PCE were within the management range of 1E-06 to 1E-04 that EPA uses to manage WWTP site risks. PCE concentrations detected in groundwater were upgradient of the former WWTP structures and were below the EPA MCL of 5 µg/L for drinking water.
- Cobalt in groundwater—Cobalt is a COC for groundwater for the child resident scenario. Cobalt posed an HQ of 2 in the child resident scenario. Cobalt was detected in three of the seven wells, with concentrations ranging from 3.9 µg/L at MW4 to 7.1 µg/L at MW6. However, cobalt is within the background range of 0.61 to 18.6 µg/L. Therefore, the slightly elevated HQ for exposure to cobalt-containing groundwater is reflective of background exposure.

Based on the following uncertainties and conclusions, there is minimal human health risk identified for the WWTP site related to site contaminants resulting from potential source areas:

- Although arsenic concentrations resulted in unacceptable risk for several scenarios, arsenic concentrations in soil and groundwater are consistent with background.
- The risk associated with benzo(a)pyrene in sludge was at the lower end of the risk management goal.
- Although there is potential risk from groundwater consumption and contact because of PCE concentrations at one well, the impacted well is located upgradient of the source area at the WWTP site, indicating the presence of PCE is likely related to an upgradient site. Additionally, the one detected PCE concentration is less than the EPA MCL for drinking water.
- Although there is noncancer risk associated with cobalt in groundwater, similar to arsenic, the detected concentrations are consistent with background.
- No COCs with vapor intrusion potential were identified in media at the concentrations observed. Therefore, vapor intrusion is an incomplete exposure pathway, and further evaluation was not necessary in the risk assessment.

1.3.3 Ecological Risk Assessment

The Screening Level Ecological Risk Assessment (SLERA) was performed as part of the RI (WESTON, 2013) to evaluate the potential ecological effects from exposure to the contaminants at the WWTP site. The multi-pathway analysis was based on reasonable, protective assumptions about the potential for ecological receptors to be exposed to and/or adversely affected by exposure to contaminants of potential ecological concern (COPECs). To establish the list of COPECs, the EPA Region 3 Biological Technical Assistance Group (BTAG) Screening Benchmarks and other available sources were used to screen soil, sludge, sediment, groundwater, and surface water for ecological risks. Food chain modeling was conducted for COPECs meeting the following criteria:

1. Constituents whose maximum concentration exceeded the ecological benchmark.
2. Constituents for which ecological benchmarks were not available.
3. Bioaccumulative compounds.

To determine whether fish potentially entering the upper portion of the unnamed tributary adjacent to the WWTP site could be impacted by contaminated surface water or sediment, potential concentrations of COPECs in fish tissue were modeled for comparison with literature-based data on toxicological effects. The projected fish tissue concentration was modeled based on derivation of bioaccumulation factors (BAFs) using data previously collected on fish and sediment in Little Mosquito Creek during the ecological risk assessment of Sites 14 and 15 (WESTON, 2011). A drainage map is provided in **Figure 1-4**.

Specific results of the SLERA evaluation are summarized in the following subsections.

1.3.3.1 Terrestrial Ecosystem

1. Maximum concentrations of metals in soil (aluminum, antimony, cadmium, iron, lead, manganese, mercury, vanadium, and zinc) as well as 4,4,-DDT, dieldrin, and Aroclor-1260 exceeded soil ecological benchmarks at the WWTP site. Of these, antimony, lead, zinc, and dieldrin exceeded WFF background soil concentrations. Lead concentrations are related to flaking lead-based paint on the exterior of the Pump House. All chemicals detected within background range were retained along

with chemicals detected above background ranges, chemicals for which no benchmarks were available (cyanide, bis[2-ethylhexyl)phthalate, acetone, MEK, and MIBK), and bioaccumulative chemicals (mercury and DDT compounds) for analysis of potential food chain impacts using modeling. PCBs were not analyzed as part of the background evaluation, thus Aroclor-1260 was also retained for further assessment.

2. Food chain HQ modeling of COPECs in soil indicated that the American robin and short-tailed shrew will be at risk from ingestion of soil invertebrates. Modeling using the no observed adverse effect level (NOAEL) as a toxicological reference indicated risks from robins ingesting soil invertebrates contaminated with DDD, DDE, DDT, Aroclor-1260, aluminum, lead, mercury, vanadium, and zinc. Modeling using the lowest observed adverse effect level (LOAEL) as a toxicological reference indicated risks from robins ingesting soil invertebrates contaminated with DDT, aluminum, lead, mercury, and zinc. Modeling using the NOAEL indicated risks to shrews from Aroclor-1260, antimony, lead, and vanadium. Modeling using the LOAEL indicated risks to shrews from lead and vanadium. Concentrations of DDT, aluminum, mercury, and vanadium in soils at the WWTP site are within the range of the concentrations detected in the background investigation (TetraTech, 2004). Background ranges are not available for DDD, DDE, Aroclor-1260, and antimony. Concentrations of lead and zinc in WWTP site soil exceeded the background range, but lead in soils is associated with flaking lead-based paint from the exterior of the Pump House.

3. The detected concentrations of several chemicals (i.e., Aroclor-1260, lead, and zinc) were elevated at one soil sample location, SS1. As noted in Sections 5.2.1 and 8.4.3.1 of the Final RI report (WESTON, 2013, because sample location SS1 is adjacent to the Pump House, it was determined that the lead in SS1 is associated with lead-based paint flaking from the exterior of the Pump House. As a result of eligibility restrictions under DERP-FUDS to conduct response actions to abate lead-based paints and other factors, the potential for soil or groundwater contamination due solely to lead-based paint from building maintenance or demolition activities is not addressed. The detection of Aroclor 1260 is considered an outlier because its detection in SS1 is the only detection of this constituent in the 26 soil samples collected at the WWTP. Aroclor 1260 was not detected in any sediment, surface water, or groundwater sample collected from the WWTP. Because lead and Aroclor 1260 were both considered outliers in SS1 and the single elevated zinc concentration was also detected at sample location SS1, zinc was also considered an outlier. As noted in Section 8.4.3.1 of the Final RI report (WESTON, 2013), after excluding data from location SS1, the 95% upper confidence levels (UCLs) were re-calculated for chemicals with an HQ greater than one for either the robin or short-tailed shrew (DDT compounds, aluminum, antimony, lead, mercury, vanadium, and zinc). The re-calculation showed that removing soil contamination at location SS1 will reduce the HQ for shrews to <1 (using the LOAEL) for all contaminants except aluminum and vanadium, which fall within background concentrations. Removing soil contamination at SS1 will reduce the HQ for robins to <1 (using the LOAEL) for all contaminants except aluminum, lead, mercury, and zinc. Aluminum and mercury concentrations fall within background. The remaining lead concentrations will result in an HQ of 2.1 reduced from an HQ of 99. The remaining zinc concentrations will result in an HQ of 1.5 to

robins reduced from 3.9. Given the low degree of risk over a limited geographic area, population impacts to these species are unlikely.

4. The remaining receptors (red fox, red-tailed hawk) modeled did not show evidence of potential ecological risks from soil.
5. Three sludge samples collected from the WWTP site (one sample from each of the sludge drying beds and one from a settling tank) contained within the former concrete infrastructure, but open to the air, exhibited maximum concentrations of the metals aluminum, antimony, cadmium, chromium, copper, iron, lead, manganese, mercury, silver, vanadium and zinc; dieldrin; DDT compounds; PAHs; and toluene that exceeded ecological benchmarks. Concentrations of several metals (e.g., lead at 530 mg/kg, mercury at 28 mg/kg, silver at 130 mg/kg, and zinc at 680 mg/kg) exceeded background concentrations. As previously stated, the maximum concentrations of metals detected were in the sludge samples collected from the sludge drying beds, SL02 and SL03. PAH concentrations were also detected in excess of background concentrations (e.g., anthracene at 630 mg/kg, benzo(a)anthracene at 2,100 mg/kg, benzo(a)pyrene at 910 mg/kg, and benzo(b)fluoranthene at 4,800 mg/kg). No further ecological evaluation was conducted in the RI because the areas are small and contained. However, if the sludge beds were used as primary habitat for ecological receptors or if a release occurred in the future, it could result in ecological risk. The settling tank is not considered a potential primary habitat due to a combination of a small opening and large depth-to-water. Therefore, potential remedial alternatives for the two sludge drying beds are evaluated as part of the WWTP site FFS.

1.3.3.2 Aquatic Ecosystem

1. Concentrations of aluminum, barium, iron, and manganese in the one surface water sample collected from the unnamed tributary of Little Mosquito Creek exceeded the respective Region 3 BTAG freshwater ecological benchmarks and thus represent a potential contamination source to Little Mosquito Creek. However, as noted in Sections 8.4.1.2 and 8.6.2 of the Final RI report (WESTON, 2013), prior downstream surface water data collected as part of the Sites 14 and 15 RI did not indicate exceedances of these metals in Little Mosquito Creek (WESTON, 2011); therefore, there is little likelihood of impact within the estuarine ecosystem of the creek due to the WWTP site. A detailed drainage map was provided as Figure 1-4 in the Final RI report (WESTON, 2013).
2. Groundwater concentrations of metals (aluminum, barium, iron, and manganese) collected from the three wells closest to the unnamed tributary (MW4, MW6, and MW7) exceeded BTAG Region 3 freshwater surface water screening benchmarks. However, groundwater concentrations fell within the range of background groundwater concentrations detected in the background investigation (TetraTech, 2004). As a result, it is unlikely that any surface water impacts are attributable to groundwater from former WWTP activities.
3. No analytes were detected in sediment within the unnamed tributary to Little Mosquito Creek at concentrations that exceeded ecological screening benchmarks.

Modeling undertaken to evaluate whether fish potentially entering the upper portion of the unnamed tributary to Little Mosquito Creek could be at risk indicated that modeled tissue concentrations will not exceed toxicological effects levels reported in Jarvinen and Ankley (1999). Food chain HQ modeling indicated that no HQs greater than 1.0 were noted for any of the receptors evaluated.

1.4 FFS FOCUS

Based on the results of the HHRA and SLERA conducted in the RI, this WWTP site FFS focuses on the development and analysis of remedial alternatives to address a potential risk to ecological receptors from contaminated sludge. The results of the HHRA conducted during the RI indicated that no unacceptable human health risk is associated with the contaminated sludge.

Three sludge samples collected in an area within the former concrete infrastructure but open to the air exhibited maximum concentrations of the metals aluminum, antimony, cadmium, chromium, copper, iron, lead, manganese, mercury, silver, vanadium, and zinc; the pesticides dieldrin and DDT compounds; PAHs; and toluene that exceed ecological benchmarks. As a result, these constituents were initially considered COPECs. Concentrations of several metals (e.g., lead at 530 mg/kg, mercury at 28 mg/kg, silver at 130 mg/kg, and zinc at 680 mg/kg) exceeded background concentrations. PAH concentrations were also detected in excess of background concentrations. No further ecological evaluation of the sludge was conducted during the RI because the area was determined to be small, contained, and not adequate as a primary habitat for ecological receptors.

In the RI, it is concluded that the remaining ecological risks related to the sludge occur over a very limited area and are considered minimal. Supplemental food chain modeling of the COPECs listed above and of modeled receptors was conducted as part of the FFS. The results of this modeling are discussed in Section 2.1.1 and provided as Appendix A. As a result of the supplemental food chain modeling, only chromium, mercury, DDD, and DDE are identified as COPECs (HQ greater than 1.0) with respect to the modeled receptors (American robin and short-tailed shrew). The supplemental food chain modeling results (Appendix A) indicate that the American robin and short-tailed shrew have the potential to be at risk from the ingestion of invertebrates due to the concentrations of chromium, mercury, DDD, and DDE present in WWTP site sludge in the two drying beds and thus are a primary focus of this FFS. The sludge within the two drying beds is partially contained within concrete walls that are open to the atmosphere. The sludge within the settling tanks is minimal and enclosed by the concrete walls of the WWTP. The metals and pesticides are unlikely to migrate from the containment areas unless the integrity of the structures is compromised. Completion of the FFS is warranted to assess various remedial alternatives, including potential land use controls (LUCs) at the WWTP site, to address the potential risks posed to the American robin and short-tailed shrew from chromium, mercury, DDD, and DDE in sludge.

SECTION 1

FIGURES

Legend

Site Area

0 500 1,000 Feet

N

Imagery Source: 2007 NASA Color Orthophoto

Prepared For:

Baltimore District **Norfolk District**

Contract No.: W91236-08-D-0050
Delivery Order No.: 0001

Prepared By:

WESTON SOLUTIONS
501 Independence Parkway
Suite 100
Chesapeake, VA 23320

Figure 1-1

Study Area Location Map
Former Wastewater Treatment Plant
Wallops Flight Facility
Accomack County, Virginia

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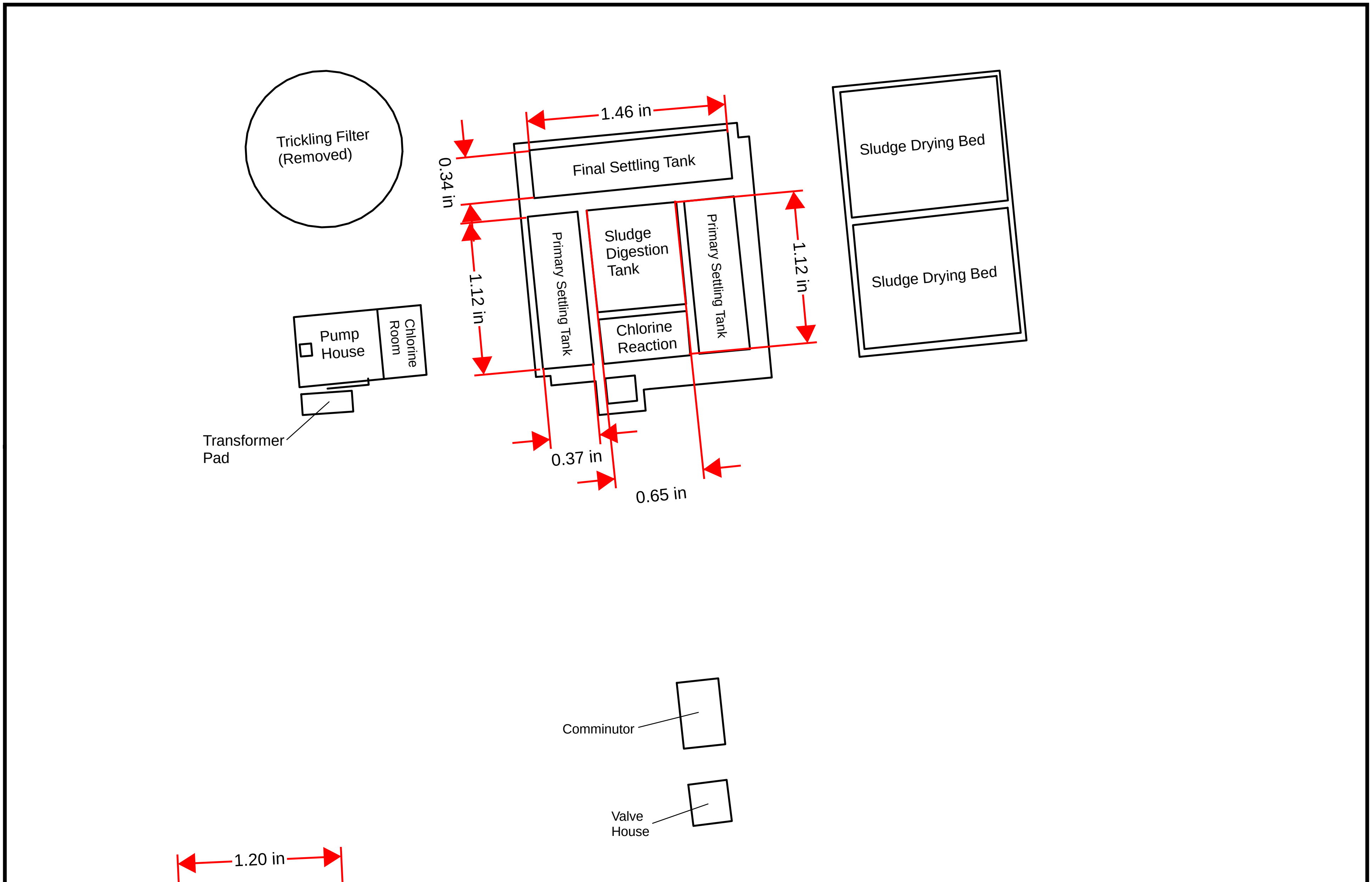
Site WWTP - RI Report\Figures\Fig 2-2_Study Area Location_1.mxd, 11 January 2010, schrotp



Legend

Structure

Imagery Source: NASA

Prepared For:

Baltimore District

Norfolk District

Contract No.: W91236-08-D-0050
Delivery Order No.: 0001

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501 Independence Parkway
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Figure 1-2

WWTP Components Map
Former Wastewater Treatment Plant
Wallops Flight Facility
Accomack County, Virginia

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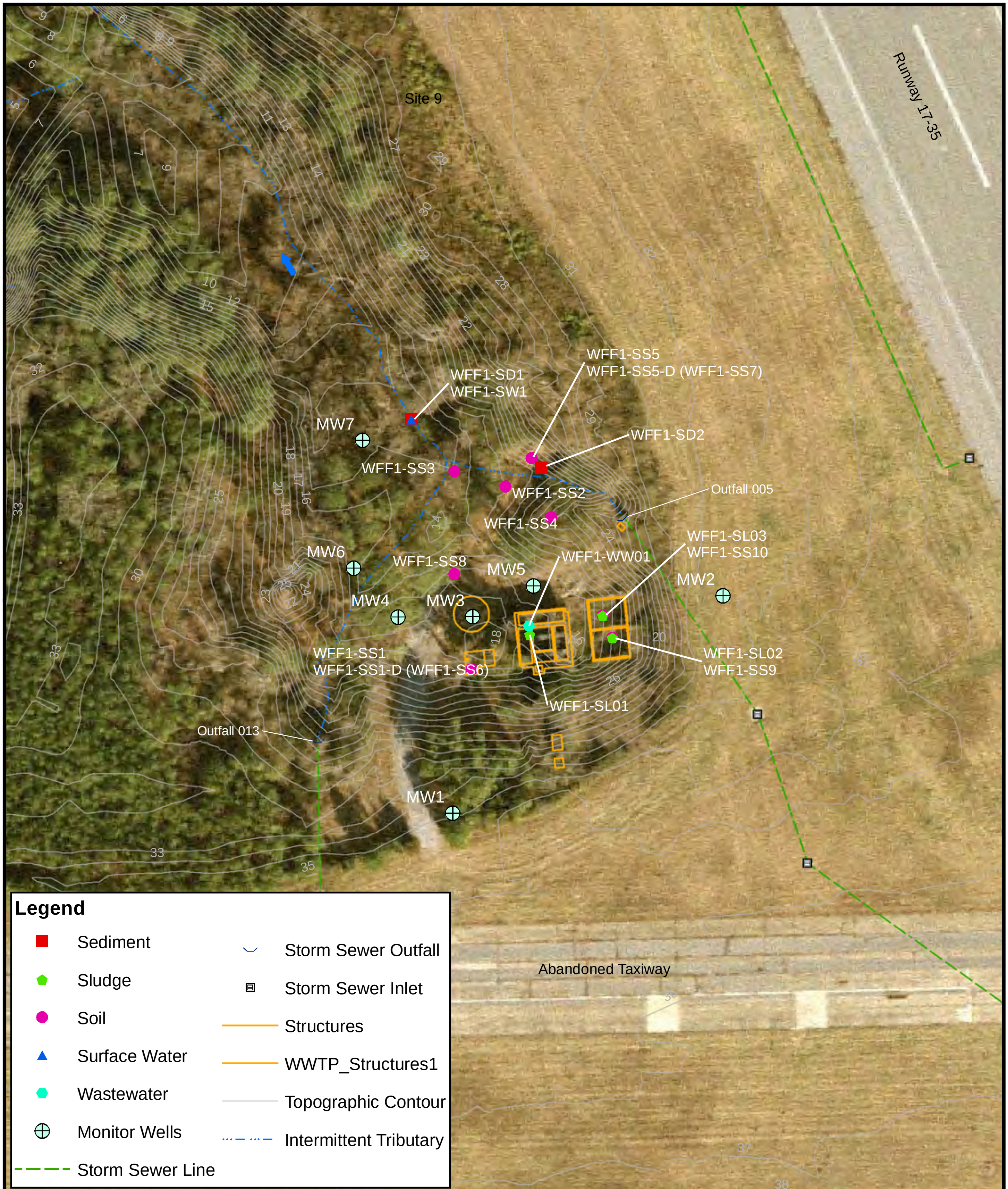
Site WWTP - RI Report\Figures\Fig 3-2_WWTP Components_1.mxd, 11 January 2010, schrotp



0 25 50 75 100 Feet

N

Topographic contour interval = 1 foot.

Imagery Source: 2007 NASA Color Orthophoto

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Baltimore District **Norfolk District**

Contract No.: W91236-08-D-0050
Delivery Order No.: 0001

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Figure 1-3

Sample Location Map
Former Wastewater Treatment Plant
Wallops Flight Facility
Accomack County, Virginia

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Site WWTP - RI Report\Figures\Fig 4-1_Sample Location_1.mxd, 11 January 2010, schrotp

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Delivery Order No.: 0001

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Figure 1-4

Study Area Drainage Map
Former Wastewater Treatment Plant
Wallops Flight Facility
Accomack County, Virginia

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2. REMEDIAL ACTION OBJECTIVES

2.1 DEVELOPMENT OF REMEDIAL ACTION OBJECTIVES

RAOs are site-specific, initial cleanup objectives established on the basis of the nature and extent of contamination, the resources that are currently and potentially threatened, and the potential for human and environmental exposure. In accordance with the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA, 1988), RAOs should specify human health, ecological, and environmental COCs, exposure pathways and receptors, and acceptable constituent levels or ranges of levels for each exposure pathway.

2.1.1 Risk Assessment Summary

The results of the BHHRA, SLERA, and the supplemental food chain modeling are used to determine the COCs and the specific media (sediment, surface water, groundwater, wastewater, sludge, or soils) impacted by these COCs that need to be addressed in the FFS, including the establishment of preliminary remediation goals (PRGs) and the development of remedial alternatives.

Although arsenic concentrations resulted in unacceptable risk to human health for several scenarios, arsenic concentrations in soil and groundwater are consistent with background. The risk associated with benzo(a)pyrene in sludge was at the lower end of the risk management range. Although there is apparent risk from PCE in groundwater, the affected well is located upgradient of the WWTP site. Additionally, the one detected PCE concentration is less than the EPA MCL for drinking water. Although there is a potential noncancer risk associated with cobalt in groundwater, cobalt concentrations are consistent with background. Vapor intrusion was considered to be an incomplete exposure pathway.

Supplemental food chain modeling was conducted for the American robin and the short-tailed shrew using site-specific concentrations of detected chemicals in sludge (maximum detected concentrations) and bioconcentration factors (BCFs) or BAFs to model earthworm tissue concentrations. The supplemental food chain modeling indicated that the American robin and short-tailed shrew have the potential to be at risk from the ingestion of invertebrates due to the concentrations of chromium, mercury, DDD, and DDE present in WWTP site sludge.

Based on the results of the BHHRA and supplemental food chain modeling, the evaluation of remedial alternatives for WWTP site sludge is included in the FFS. Ecological-based PRGs were developed for chromium, mercury, DDD, and DDE (Appendix A).

2.1.2 Remedial Action Objectives

Based on the ecological COPECs and the exposure pathways and receptors present at the WWTP site, the following RAOs were developed for the WWTP site:

- Prevent the exposure of the American robin and short-tailed shrew via ingestion of invertebrates to chromium, mercury, DDD, and DDE concentrations in WWTP site sludge at levels above PRGs.

2.2 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

2.2.1 Definition of ARARs

The NCP and Section 121 of CERCLA require that CERCLA remedial actions attain federal and state ARARs unless specific waivers are granted. The ARAR analysis is directed at substantive, promulgated regulations with regard to on-site activities (CERCLA § 121(d), 42 United States Code [U.S.C.] § 9621(d); NCP, 40 CFR § 300.5). Furthermore, CERCLA response actions, in accordance with CERCLA/NCP, are exempt from permits and similar procedural requirements with regard to on-site activities (42 U.S.C. § 9621(e)(1); 40 CFR § 300.400(e)(1)). In relation to off-site activities (e.g., transportation and off-site disposal), compliance is required for applicable substantive and procedural requirements, i.e., NCP (federal and state), 40 CFR § 300.400(e)(2). Such off-site activities are not part of the ARAR or TBC analysis, but rather may be discussed under the implementability factor to the extent that they pose challenges for certain alternatives.

Pursuant to the NCP, 40 CFR § 300.5, ARARs are defined as follows:

Applicable Requirements: Applicable requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable.

Relevant and Appropriate Requirements: Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not ‘‘applicable’’ to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

TBC Criteria: In addition to ARARs, appropriate advisories, criteria, or guidance for a particular release may be identified. For example, where no specific ARAR exists for a chemical or situation, or where such an ARAR is not sufficient to be protective of human health or the environment, appropriate federal and/or state guidance or advisories may be considered in determining the necessary level of cleanup for protection of public health and the environment.

ARARs and TBCs are used to develop remedial actions, to help establish PRGs, to scope and formulate remedial action alternatives, and to govern implementation and operation of the selected remedial alternatives. Discussions of ARARs and TBC criteria are provided in the following subsections.

2.2.2 Development of ARARs and TBCs

ARARs and TBCs are developed on a site-specific basis. ARARs and TBCs are further categorized as chemical-specific, location-specific, or action-specific:

Chemical-Specific: Chemical-specific ARARs/TBCs are usually health- or risk-based numerical values or methodologies which, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the environment.

Location-Specific: Location-specific ARARs/TBCs are restrictions placed on the concentration of hazardous substances or the conduct of activities solely because they are in specific locations. Some examples of special locations include floodplains, wetlands, historic places, and sensitive ecosystems or habitats.

Action-Specific: Action-specific ARARs/TBCs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous wastes. These requirements are triggered by the particular remedial activities that are selected to accomplish a remedy.

2.2.3 Identification of Site ARARs and TBC Criteria

Preliminary lists of chemical-specific and action-specific ARARs and TBC criteria are presented in **Tables 2-1** and **2-2**, respectively. No location-specific ARARs were identified for the WWTP site. The list of state ARARs was constructed from a preliminary ARAR list submitted by VDEQ to USACE in May 2014. A list of ARARs and TBC criteria will be included in the Record of Decision (ROD) for the WWTP site.

Note that ARARs do not include permits, procedural, or administrative requirements. Nor do they include local laws/regulations. Furthermore, a prerequisite for being an ARAR is that it must be enforceable.

Additionally, ARARs do not include occupational safety or worker protection requirements. However, the NCP (40 CFR § 300.150) requires compliance with certain Occupational Safety and Health Administration (OSHA) standards and other worker protection requirements.

2.2.3.1 Chemical-Specific TBC Guidance

Federal TBCs are included in **Table 2-1**. There are no promulgated federal or VDEQ standards for the COCs in soil based on ecological receptors; therefore, there are no chemical-specific ARARs. However, EPA and state guidance exists for screening purposes and for evaluation of risk, as shown in **Table 2-1**. Chemical-specific ARARs are not available for sludge COPECs on which to base PRGs; thus, site-specific PRGs were calculated using TBCs. A summary of the development of the PRGs is presented in Section 2.2.4. PRGs will be determined in consultation with EPA and VDEQ and will be presented in the ROD for the WWTP site.

2.2.3.2 Action-Specific ARARs

Based on the remedial action alternatives developed for soil remediation at the WWTP site, certain action-specific ARARs may be applicable or relevant and appropriate. Federal and state action-specific ARARs are included in **Table 2-2**. Action-specific ARARs will be determined in consultation with federal and state agencies and will be published in the ROD.

2.2.3.3 Development of Preliminary Remediation Goals

PRGs are acceptable contaminant levels for each chemical constituent and exposure route. During the RI, screening levels were used for comparison to actual concentrations to illustrate the nature and extent of contamination at the WWTP site and identify the COPCs. The COPCs are subsequently evaluated for risk to receptors, and PRGs are developed in an FFS based on the anticipated land use, the BHHRA results, and the SLERA results; therefore, the PRGs serve as contaminant levels protective of the environment and human health under commercial/industrial land use.

2.2.3.4 COPCs and COPECs

Although COCs were identified for human health, no unacceptable risks to human health were identified at the WWTP site because risks to potential future residents were not evaluated. The future resident exposure pathway was considered incomplete because it was assumed any future development of the site for residential use would necessitate removal of the sewage sludge and sediment in the settling basins. Further, COCs were either within background ranges, within acceptable risk management ranges or due to the presence of flaking paint. COPECs for the WWTP site were identified based on the results of the BHHRA, SLERA, and the food chain modeling. The list of COPECs also includes the receptor group for which risk was determined. Under the identified assumptions, the only risk identified was ecological and associated with the sludge from the two drying beds, which is currently partially contained within concrete walls.

Ecological sludge COPECs associated with risk to the American robin and short-tailed shrew are as follows:

- Chromium
- Mercury
- DDD
- DDE

2.2.3.5 Exposure Pathways and Receptors

The identification of exposure pathways and receptors is important in developing RAOs because human health and environmental protection may be achieved by reducing exposure (such as containment or access limitations for human health, and containment or removal for ecological receptor health). The BHHRA for the WWTP site evaluated carcinogenic and noncarcinogenic risks associated with exposure to chemical contaminants at the WWTP site under a No Action alternative (i.e., in the absence of a remedial [corrective] action). The BHHRA evaluated the following receptor groups: adolescent trespasser, future commercial/industrial worker, and future construction worker, and hypothetical future residents (age-adjusted, adult, and child). The WWTP site is currently not used for residential purposes, and no future residential use is planned; however, the residential scenario was evaluated to determine an upper limit for the BHHRA. The food chain HQ modeling of COPECs identified only one pathway (American robin and short-tailed shrew ingestion of soil invertebrates in sludge) as unacceptable for ecological risk.

2.2.3.6 Identification of Acceptable COPEC Concentrations

Numerical PRGs representing contaminant levels protective of the environment were calculated for the COPECs based on the receptor groups and exposure pathways. The risk-based PRGs were derived for COPECs and receptor groups identified as a concern for the WWTP site. A summary of the proposed PRGs is presented in **Table 2-3**.

In calculating the PRGs for each ecological-based COPEC, the same methodology used to calculate the HQs for each COPEC was used, which included a reverse calculation of the PRG based on a target HQ (THQ) of 1.0.

Formulas used include the following:

COPEC-Calculated PRG concentration = exposure point concentration (EPC)/THQ

THQ of 1.0 = Adjusted dose * LOAEL

Adjusted dose = Dose * % earthworm in diet

Dose = Concentration in earthworm * food ingestion rate / body weight * area use factor

Concentration in earthworm = EPC * BCF (or BAF)

The calculated PRG values for the COPECs were compared with the anthropogenic background concentrations for WFF. The maximum of the two values (calculated PRG concentrations and background upper tolerance limits [UTLs] concentrations at WFF) was selected as the PRG. The UTLs for soils were calculated and have been computed based upon extracted background data sets and estimated by 95th UTLs (TetraTech, 2004). UTLs were calculated for several metals. The proposed PRGs for the WWTP site are presented in **Table 2-3**.

The risk-based PRGs were derived for the COPECs (chromium, mercury, DDD, and DDE) and receptors (American robin and short-tailed shrew) identified as a concern for the WWTP site. PRGs for the protection of human health were not calculated because there were no unacceptable risks to human health receptors; therefore, the PRGs for the WWTP site are based on the protection of ecological receptors (American robin and short-tailed shrew). These PRGs are presented in **Table 2-3**.

2.3 AREAS AND VOLUME OF CONTAMINATION

Based on the RAOs identified in Section 2.1.2 and the PRGs established in Section 2.2.4.3, the areas and volumes of contamination were calculated for the WWTP site. The areas and volumes of contamination are considered protective of ecological health. A discussion of how the area and volume of contamination for the WWTP site was calculated is presented below.

The suspected contaminant source at the WWTP site is the sludge in the drying beds and settling tanks. At the drying beds, the depth of COPEC contamination is 2 feet based on the sludge samples collected from the 0- to 2-foot interval. Each drying bed measures 18.5 feet by 24 feet, which results in 32.89 cubic yards of sludge for each drying bed. However, to be conservative, and given the uncertainty regarding the actual depth of COPEC contamination, a volume of 33 cubic yards for each drying bed is used in the FFS. At the settling tanks, a minimal amount of sludge is present and conservatively estimated to average 6 inches in depth at each settling tank. The total area of the settling tanks is approximately 890 square feet; therefore, the volume of sludge in the settling tanks is approximately 445 cubic feet or 16.5 cubic yards.

The estimates of the remediation area and the volume are for the purposes of evaluating the alternatives in the FFS, and a more accurate estimate of area/volume will be made during the remedial design/remedial action phase.

The above estimates reflect a scenario in which all sludge within the two drying beds and settling tanks would be remediated; therefore, the total volume of sludge in the drying beds and settling tanks is approximately 82.5 cubic yards (33 + 33 + 16.5).

SECTION 2

TABLES

Table 2-1
Potential Chemical-Specific TBC Criteria
Focused Feasibility Study Report, WWTP Site, WFF, Virginia

Regulation or Guidance	TBC	Applicability
EPA Region 3 Regional Screening Level (RSL) Tables	TBC	Media cleanup targets based on human exposure for industrial and residential use scenarios. For a single contaminant in a single medium, under standard default exposure assumptions, the TBC corresponds to the target risk or hazard quotient. However, the RSLs for noncarcinogens are adjusted by a factor or 0.1 in order to account for the cumulative effects of multiple contaminants.
EPA Region 3 Biological Technical Assistance Group (BTAG) Draft Screening Levels for Ecological Risk-Soil	TBC	May aid in determining soil cleanup criteria by calculating ecological receptor exposures to contaminated soil using BTAG screening levels.

Table 2-2
Potential Action-Specific ARARs
Focused Feasibility Study Report, WWTP Site, WFF, Virginia

Regulations or Guidance	ARAR	Applicability
Virginia Pollutant Abatement (VPA) Permit Regulation, 9 Virginia Administrative Code (VAC) 25-32-10 through 300.	ARAR	The provisions of the *Virginia Pollutant Abatement (VPA) Permit Regulation* regulate any discharge of pollutants adjacent to State waters (including groundwater). The substantive provisions of these regulations are ARARs to the extent that Alternatives 1 to 3 are viewed as a form of on-site sewage sludge disposal or treatment. The alternatives will comply with the substantive requirements of these regulations only (No permit is required.). Alternative 4, constituting off-site disposal at a VDEQ-authorized landfill facility, is exempt under 9 VAC 25-32-40, paragraph 4.
Virginia Ambient Air Quality Standards, 9 VAC 5-50-80 and 90 *Standards of Performance for Visible Emissions and Fugitive Dust/Emissions [Rule 5-1]*, 9 VAC 50-50-60 to 120	ARAR	Promulgated by the Virginia Air Pollution Control Board under the requirements of the Federal Clean Air Act, these regulations set policies and procedures to limit fugitive particulate matter produced by construction activities and regulate all other types of potential air impacts. The substantive requirements are applicable but not the administrative/procedural requirements. These standards are ARARs for all active remedies (Alternatives 2, 3, and 4) that include dust generation or the generation of any air contaminants from the remedial action alternatives considered. Reasonable precautions should be taken to prevent particulate matter from becoming fugitive during construction of the low-permeability cap or during removal activities.

Table 2-3
Ecological Preliminary Remediation Goals
Focused Feasibility Study Report, WWTP, WFF, Virginia

Sludge COPEC	American Robin PRG[1]	Short-tailed Shrew PRG[1]	Background[2]	PRG (mg/kg)[3]
Chromium	6.11E+01	NC	2.33E+01	6.11E+01
Mercury	5.38E-01	1.84E+01	6.75E-01	6.75E-01
DDD	3.42E-01	NC	NA	3.42E-01
DDE	1.43E-01	NC	NA	1.43E-01

mg/kg – milligram per kilogram.
[1]PRG = Exposure Point Concentration / HQ
[2]background upper tolerance limits concentrations at WFF for soils (TetraTech, 2004)
[3]PRG calculated as the maximum of the calculated PRG and the anthropogenic background concentrations for WFF
NA = Not available
NC = PRG Not Calculated as HQ < 1.0

3. IDENTIFICATION AND SCREENING OF TECHNOLOGIES

This section describes general remedial actions and potential remedial technologies for the WWTP site. The general remedial actions identified are analyzed in Section 4 (Development of Alternatives) and in Section 5 (Detailed Analysis of Alternatives). Each potential remedial technology identified in this section is screened for effectiveness, implementability, and cost to evaluate its viability at the WWTP site.

3.1 GENERAL REMEDIAL ACTIONS

General remedial actions are those actions that will achieve the RAOs. The general remedial actions considered for the WWTP site are as follows:

- **No Action**—The No Action alternative is evaluated to satisfy the NCP requirement of 40 CFR 300.430(e)(6), which requires consideration of this alternative as a baseline against which other alternatives may be compared.
- **Land Use Controls**—LUCs include any type of physical, legal, or administrative mechanism that restricts the use of, or limits access to, real property to prevent or reduce risks to human health and the environment. Physical mechanisms encompass a variety of engineered remedies to contain or reduce contamination and/or physical barriers to limit access to property, such as fences or signs. The legal mechanisms used for LUCs are generally the same as those used for institutional controls (ICs) as discussed in the NCP. ICs are a subset of LUCs and are non-engineered instruments, such as legal and administrative controls. Legal controls include restrictive covenants, negative easements, equitable servitudes, and deed notices. Administrative controls include notices, adopted local land use plans and ordinances, construction permitting, or other existing land use management systems that may be used to ensure compliance with use restrictions.
- **Containment**—Containment refers to technologies (such as a low-permeability cap) used to prevent or redirect the transport mechanisms from contact with contaminated media and to isolate contaminants from human and ecological contact. Containment limits or controls the migration of contaminants beyond the present area of contamination into adjacent areas, but does not contribute to reducing the toxicity or volume of contamination.
- **Removal and Disposal**—Treated or untreated wastes can be disposed of either on- or off-site. Disposal options determine the ultimate location of treated or untreated media in an environmentally sound, publicly acceptable, and cost-effective manner. Disposal actions typically do not involve reduction of the toxicity or volume of the contaminated media, but may in certain circumstances, reduce contaminant mobility due to associated containment. Sludge disposal serves to remove the source of risk to human health and the environment by disposing of excavated sludge and debris. These technologies are used in combination with removal actions.

Based on the relatively low COPEC concentrations and minimal volume of contaminated sludge, treatment technologies were not considered a cost-effective option for the WWTP site. Effective in situ or ex situ treatment technologies for the COPECs (metals and organic pesticides) would require a combination of treatment technologies. However, the technologies effective for remediation of metals are not effective for remediation of organic pesticides, thus increasing the costs to treat the sludge. Metals and some organic pesticide treatment technologies require the input of chemical reagents, which can be expensive and hazardous. Difficulties may be encountered with obtaining the necessary contact between reagents and COPECs in the sludge matrix for the reagents to be effective, and some post-treatment processing may be required. Furthermore, the products of treatment may be phytotoxic, thus sterilizing soils.

The COPECs at the WWTP site have concentrations below those associated with hazardous waste and are at levels that allow soils to be disposed at Resource Conservation and Recovery Act (RCRA) Subtitle D disposal facilities (e.g., solid waste landfills). Treatment technologies may result in more adverse impacts and higher costs for similar levels of protectiveness than other available approaches. Therefore, treatment technologies were neither identified nor evaluated in this FFS.

It is not expected that the contaminated sludge potentially to be removed from the WWTP site will be classified as a listed hazardous waste through application of the RCRA "contained-in" policy because no specific listed hazardous waste source has been identified. In addition, based on the total results, it is not anticipated that the sludge will exhibit hazardous waste characteristics.

3.2 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

3.2.1 Screening Criteria

Remedial technologies are first evaluated against three general categories of effectiveness, implementability, and cost to ensure that they meet the minimum standards of the criteria within each category. The three general categories are first used to screen the technologies described in Section 3.2.2 and later used to screen the alternatives developed in Section 4.1. The three general categories are described below.

3.2.1.1 Effectiveness

Technologies or alternatives that have been identified should be evaluated further on their effectiveness relative to other processes within the same technology/alternative type. The evaluation should focus on (1) the potential effectiveness of technology/alternative options in handling the estimated areas or volumes of media and meeting the PRGs identified in the RAOs; (2) the potential impacts to human health and the environment during the construction and implementation phase; and (3) how proven and reliable the technology/alternative is with respect to the contaminants and conditions at the WWTP site.

3.2.1.2 Implementability

Implementability, as a measure of both the technical and administrative feasibility of constructing, operating, and maintaining a remedial action alternative, is used during screening to evaluate the combinations of technology/alternative options with respect to conditions at a specific site. Technical feasibility refers to the ability to construct, reliably operate, and meet technology-specific regulations for technology/alternative options until a remedial action is complete. It also includes operation and maintenance (O&M), replacement, and monitoring of the technical components of a technology/alternative, if required, after the remedial action is complete. Administrative feasibility refers to the ability to obtain approvals from other offices and agencies; the availability of treatment, storage, and disposal services and capacity; and the requirements for, and availability of, specific equipment and technical specialists.

The determination that a technology/alternative is not technically feasible usually precludes it from further consideration unless steps can be taken to change the conditions responsible for the determination. Typically, this type of "fatal flaw" is identified during technology screening, and an alternative consisting of an infeasible technology is not considered further. Negative factors affecting administrative feasibility normally involve coordination steps to lessen the negative aspects of the technology/alternative but do not necessarily eliminate a technology/alternative from consideration.

3.2.1.3 Cost

Typically, technologies/alternatives are sufficiently defined prior to screening so that estimates of cost are available for comparisons among technologies/alternatives. However, uncertainties associated with the definition of technologies/alternatives often remain, so it may not be practicable to define the costs of technologies/alternatives with the accuracy desired for the detailed analysis (i.e., +50% to -30%) (EPA, 1988).

According to EPA guidance, a high level of accuracy in cost estimates during screening is not required. The focus should be on making comparative estimates for technologies/alternatives with relative accuracy so that cost decisions among technologies/alternatives can be sustained as the accuracy of cost estimates improves beyond the screening process.

When the costs of remedial action alternatives are evaluated (see Section 5), both capital and O&M costs are considered, where appropriate. The evaluation includes those O&M costs that will be incurred for as long as necessary, even after the initial remedial action is complete. In addition, potential future remedial action costs are considered during alternatives evaluation to the extent they can be defined. Present worth analyses are used during alternatives evaluation to evaluate expenditures that occur over different time periods. By discounting all costs to a common base year, the costs for different technologies/alternatives can be compared based on a single figure for each alternative. Each cost calculation involves estimating the time necessary to complete the proposed alternative.

3.2.2 Evaluation of Technologies

The following technologies and approaches are considered for the remediation of sludge at the WWTP site. The process options and the results of the screening process are described in the following sections. **Table 3-1** provides a summary of the screening with an indication whether to retain or reject the process option.

3.2.2.1 No Action

The No Action alternative, by definition, involves no remedial action at the WWTP site. This action has no technological barriers. The potential ecological risks to the American robin and short-tailed shrew from ingestion of soil invertebrates identified in the supplemental food chain modeling presented in the FFS report would not be addressed by this alternative. COPECs would remain in the WWTP site sludge above PRGs. This alternative would be implemented at no cost, but would not be effective at addressing the potential risk associated with WWTP site sludge. The No Action process option is retained for further consideration as required by the NCP.

3.2.2.2 Land Use Controls

LUCs include any type of physical, legal, or administrative mechanism that restricts the use of, or limits access to, real property to prevent or reduce risks to human health and the environment.

Physical mechanisms encompass a variety of engineered remedies to contain or reduce contamination and/or physical barriers to limit access to property, such as fences or signs. The legal mechanisms used for LUCs are generally the same as those used for ICs as discussed in the NCP. ICs are a subset of LUCs and are non-engineered instruments, such as legal and administrative controls. Legal controls include restrictive covenants, negative easements, equitable servitudes, and deed notices. Administrative controls include notices, adopted local land use plans and ordinances, construction permitting, or other existing land use management systems that may be used to ensure compliance with use restrictions.

Access Restrictions

The installation of fencing (fine-mesh fencing at base of fence to a depth in the subsurface) and avian netting around the WWTP site would reduce the potential for food chain exposures for the ecological receptors of concern. Construction of the fencing and avian netting would be achievable with minimal physical and chemical risks to construction workers. Construction activities would result in limited land disturbance for the installation of the fine mesh fence and posts. Access restrictions are implementable and low cost, but would not be effective in reducing COPEC concentrations below PRGs. However, access restrictions would be potentially effective at reducing overall WWTP site risks and are included for further evaluation.

Land Use Restrictions

Land use restrictions are implementable and relatively low in cost, but would not reduce risks to ecological receptors and would not be effective for the treatment of the contaminants.

3.2.2.3 Containment

The sludge at the WWTP site is partially contained within existing concrete walls. However, the sludge is exposed to the environment and is accessible as habitat for the American robin and short-tailed shrew. The integrity of the existing structure should be determined prior to selecting containment as a remedy in order to determine the ability of the structure to accommodate an additional load (e.g., horizontal barriers). Horizontal barriers evaluated include low-permeability clay, asphalt, and concrete caps. Long-term maintenance would be required in order to maintain effectiveness.

Horizontal barriers (e.g., geotextile liners and clay caps) installed above the sludge would be a potentially effective way to reduce ecological exposure to contaminated sludge at the WWTP site. These barriers would also reduce the infiltration of water into the subsurface and minimize the migration of contaminants. Potential impacts to construction workers during the construction of a horizontal barrier would be limited. Any impacts associated with direct contact or inhalation of contaminated sludge could be mitigated by means of personal protective or dust control measures. A limited environmental impact in the form of minor land disturbance (less than 10,000 square feet in size) would be anticipated as a result of the construction of a horizontal barrier. Horizontal barriers would be implementable using conventional equipment, potentially effective, and relatively moderate in cost. Additionally, horizontal caps have been used at Subtitle D landfills effectively to reduce exposure to potential COCs.

An asphalt/concrete cap is less flexible than a low-permeability clay cap and is subject to long-term degradation through weathering (including freeze-thaw processes), cracking, and subsidence. Significant degradation may result in substantial asphalt/concrete cap repairs or cap replacement. As a result of the asphalt/concrete cap long-term deficiencies identified above, the low-permeability clay cap would be the preferred horizontal barrier for use at the WWTP site. Horizontal barriers in the form of an asphalt/concrete cap are not evaluated further. Based on the potential effectiveness, horizontal barriers in the form of a low-permeability cap are included for further consideration.

3.2.2.4 Excavation and Disposal

Excavation and removal of contaminated media have been shown to be effective and implementable technologies at many HTRW sites. Application of a removal technology could be accomplished with conventional heavy construction equipment and normally would be followed by disposal of the contaminated media, if required. Excavated sludge would be transported to an approved disposal facility in accordance with applicable federal, state, and local regulations, policy, and standards. Following excavation, the excavated areas would be backfilled with clean fill material. Excavation of contaminated sludge would be highly effective because the sludge containing the COPECs above PRGs (approximately 2 feet thick) would be removed. Furthermore, removal of the sludge would be effective because the route of exposure to receptors would be eliminated. The removal of sludge would be implementable because access to and removal of the sludge would be attainable with modern equipment.

Potential environmental impacts during construction would be limited because the area and volume of material to be removed is relatively small (less than 10,000 square feet in size) and confined to the sludge drying beds and settling tanks. Potential impacts to construction workers during sludge removal would be limited. Any impacts associated with direct contact or inhalation of contaminated sludge could be mitigated by means of personal protective or dust control measures. In summary, the excavation and removal of sludge is highly effective, implementable, and moderate in cost; therefore, it is included for further evaluation.

Two options have been identified as being applicable for disposal of untreated sludge. These include on-site replacement and off-site disposal.

On-Site Replacement

Typically, on-site replacement is an effective means of reusing “clean” soils that have been separated from contaminated soils or of reusing treated soils. Because COPEC concentrations in WWTP site sludge are relatively low and potentially diffuse (the actual depth of contamination is unknown), separation of “clean” sludge from contaminated sludge would not be feasible. Therefore, on-site replacement of sludge is not evaluated further.

Off-Site Disposal Facility

The off-site disposal option would allow contaminated soils to be completely removed from the WWTP site by excavation, consolidation, and transportation to an approved facility. Disposal of hazardous and solid wastes must comply with RCRA and state regulations. Based on the COPEC concentrations in soils, disposal would be anticipated to be at RCRA Subtitle D facilities because the sludge is anticipated to be classified as solid waste, not hazardous waste. The permit of the Accomack County Landfill located at 9400 Cutler Lane in Atlantic, Virginia, allows disposal of the sludge and is less than 7 miles from the WWTP site. The off-site disposal of contaminated sludge at this facility would be effective because the contaminated sludge above PRGs would be removed from the site, thus preventing the ingestion of invertebrates by the American robin and short-tailed shrew that would result in HQs greater than 1.0. The use of an off-site disposal facility would be implementable because the Accomack County Landfill is located within a relatively short distance from the WWTP site and vehicles could easily transport the material. Minimal impacts to traffic or the environment are anticipated due to the low number of truckloads needed to transport the sludge (nine 10-cubic yard trucks or five 20-cubic yard trucks). Based on the moderate costs associated with off-site disposal in a local RCRA Subtitle D facility close to the WWTP site, off-site disposal is evaluated further.

3.2.2.5 Post-Remedial Activities

Ground cover restoration would be a highly implementable and effective means of reducing the potential for soil erosion from areas of the WWTP site that have undergone excavation or have been highly trafficked. Backfilling and regrading of excavated areas with clean fill to existing grade might be necessary, followed by appropriate seeding/re-vegetating to NASA specifications. Because ground cover restoration is a standard practice for post-remedial activities and is relatively low in cost, it is retained for further consideration.

3.2.3 Retained Process Options

The technologies and process options retained based on the initial screening for their effectiveness, implementability, and cost are summarized as follows:

- No Action.
- Land Use Controls (Access Restrictions).
- Containment (Low-Permeability Cap).
- Excavation and Disposal (Off-Site Landfill).
- Post-Remedial Activities (Ground Cover Restoration).

It should be noted that the USACE cannot implement, maintain, or enforce LUCs on property it does not own. Therefore, in keeping with Headquarters USACE policy, before LUCs can be considered a viable component of any remedy, it must be documented that the implementing and enforcing agency has committed to the implementation and enforcement of these LUCs. This documentation, if the selected remedy involves LUCs, will be placed in the ROD.

SECTION 3

TABLE

Table 3-1
Identification and Screening of Technologies

General Response Action	Remedial Technology	Process Options	Effectiveness	Technical Implementability	Screening Results
No Action	No Action	No Action	Not effective at meeting RAOs	No action required for implementation. Provides a baseline.	Retained
Land Use Controls	Proprietary Control/NASA Master Plan Restriction	Land Use Control (LUC)	Not effective at meeting RAOs	Land use restrictions would restrict the WWTP site to a specific use. Implementable with the concurrence of land owner and EPA and/or state regulators to enter a Memorandum of Understanding (MOU) providing for specific ICs.	Rejected
	Access Restriction	Fine mesh fencing/avian netting	Effective at meeting RAO with respect to achieving protectiveness by reducing ecological exposure to COPECs above PRGs.	Fencing/avian netting is implementable using conventional methods and materials.	Retained
Containment	Horizontal Barrier	Low-Permeability Cap/Cover	Effective at meeting RAO by reducing ecological exposure to COPECs.	The low-permeability clay cap would be implementable because this is a remedy often used for capping of Subtitle D landfills using conventional equipment.	Retained

Table 3-1
Identification and Screening of Technologies (Continued)

General Response Action	Remedial Technology	Process Options	Effectiveness	Technical Implementability	Screening Results
		Asphalt/Concrete Cap	Effective at meeting RAO by reducing ecological exposure to COPECs.	An asphalt or a concrete cap would act as a barrier to prevent direct contact, ingestion, and inhalation of contaminants and would reduce the migration of contaminants to groundwater. An asphalt cap or concrete is less flexible than a low-permeability clay cap and is subject to long-term degradation through weathering, cracking, and subsistence. Significant degradation may result in cap replacement. Long-term maintenance would be required. PAH residue in site soils may increase due to decayed asphalt material. Implementability would be similar to a low-permeability cap/cover.	Rejected
Excavation and Disposal	On-Site Replacement	On-Site Replacement	Effective at achieving RAOs by replacing contaminated sludge with “clean” sludge.	Based on COPEC concentrations and distribution in sludge, separation is not feasible.	Rejected
	Off Site Disposal	Off-Site Landfill	Effective at achieving RAOs through reduction in COPEC concentrations to below PRGs.	The off-site disposal of excavated sludge would be implementable with conventional equipment. A landfill has been identified that is willing to accept the sludge.	Retained

Note:

The shading indicates the option was eliminated from further consideration.

4. DEVELOPMENT OF REMEDIAL ALTERNATIVES

In this section, the process options and technologies retained during the initial screening are developed into remedial action alternatives.

The remedial alternatives discussed in this section represent a range of remedial actions in terms of cost-effectiveness, protection of the environment, and of the level of difficulty of implementation. The development of these alternatives takes into account the RAOs described in Section 2. These RAOs focus on minimizing ecological exposure to the COPECs in sludge at the WWTP site.

The process options retained in the screening process are listed in Section 3.3. Because of the limited number of appropriate technologies retained in the initial screening process (Section 3), a limited number of remedial alternatives were developed.

The four remedial alternatives for the WWTP site are described in the following subsections:

- Alternative No. 1 – No Action
- Alternative No. 2 – Land Use Controls
- Alternative No. 3 – Low-Permeability Cap Installation
- Alternative No. 4 –Sludge Removal and Off-Site Disposal

4.1 ALTERNATIVE NO. 1 – NO ACTION

Under Alternative 1, no further efforts or resources will be expended at the WWTP site. No action will be implemented to address the existing contamination in the WWTP site sludge. Alternative 1 serves as the baseline for comparing the other alternatives against the nine criteria. This alternative is required under the NCP.

4.2 ALTERNATIVE NO. 2 – LAND USE CONTROLS

The results of the BHHRA indicated that there was no unacceptable human health risk associated with WWTP site activities. The supplemental food chain modeling results indicated that the contaminated sludge COPECs pose an unacceptable ecological risk to the American Robin and short-tailed shrew from the ingestion of soil invertebrates. Although the contaminated area is small and partially contained, it is possible the sludge beds can be used as primary habitat for ecological receptors.

This alternative will manage risks through LUCs (access restrictions). Successful implementation of access restrictions will be contingent on the cooperation and active participation of the property owner and government agencies to protect environmental receptors from WWTP site risks. The property owner or representative (remedial contractor) will conduct master planning to document any WWTP site access restrictions. As part of the five-year review process, USACE will contact NASA to verify and update, if necessary, the status of the master plan restrictions and conduct a site visit to ensure the continued protectiveness of the access restrictions. The remedial design will specify steps and controls to be put in place to ensure the access restrictions are maintained, thus ensuring long-term effectiveness and permanence. Access restrictions in the form of fine mesh fencing and avian netting will be implemented to prevent ecological receptors from contacting the sludge and potentially being exposed to COPECs above PRGs.

In general, LUCs and access restrictions recommended for the WWTP site include the following:

- Signs.
- NASA Master Plan revisions are required to document access restrictions and maintenance of land use controls and restrict intrusive activities in the sludge drying bed areas.
- Installation of fine mesh fencing and avian netting.

Long-term monitoring (LTM) of the WWTP site will be warranted to ensure land use and engineered controls remain effective and protective of human health and the environment and to assess whether the access restrictions need to remain in place. The LTM program will include sampling and analysis of sludge in the current areas where concentrations of COPECs (chromium, mercury, DDD, and DDE) exceed the PRGs. Preparation of the five-year review report will also be required for Alternative 2.

4.3 ALTERNATIVE NO. 3 – LOW-PERMEABILITY CAP INSTALLATION

Alternative 3 includes the following steps:

- Installation of a low-permeability cap, consisting of a clay cover and a geotextile liner, for the contaminated sludge area.
- Dust controls.
- Installation of erosion controls.
- Ground cover restoration in the form of a vegetative cover.
- LUCs to restrict intrusive activities in the capped area.

In Alternative 3, the sludge from the areas containing contamination above PRGs will be covered with a clay cap consisting of a geotextile liner (to prevent erosion and burrowing) and approximately 2 feet of clean clay. LUCs (listed below) will also be implemented to control or manage any intrusive activities that will penetrate the soil cap, including demolition of the structure containing the sludge. Depending upon the WWTP site conditions at the time of the remedial action, dust controls might be necessary during cap construction to reduce potential exposure to workers through inhalation of contaminated particulates. Erosion controls (i.e., silt fence) will be installed as a vertical barrier around the work area to prevent the potential migration of contaminated sludge off-site via runoff. A vegetative ground cover and geotextile liner will be established on top of the soil cover for erosion control purposes. Five-year reviews will be required to demonstrate that the remedy remains protective of human health and the environment.

Sludge COPECs will remain on-site, although capped. Therefore, the following LUCs will be implemented as part of Alternative 3:

- NASA Master Plan revisions to restrict intrusive activities in the sludge drying bed areas.
- Signs.

Preparation of the five-year review report would be required for Alternative 3 to evaluate the effectiveness of the cap at achieving RAOs.

4.4 ALTERNATIVE NO. 4 – SLUDGE REMOVAL AND OFF-SITE DISPOSAL

Alternative 4 includes the following steps:

- Sampling of sludge for off-site disposal requirements.
- Installation of erosion controls.
- Dust controls.
- Excavation of contaminated sludge. Off-site disposal of excavated sludge.
- Post-excavation confirmation sludge sampling.
- Backfill of the excavated areas with clean fill material.
- Ground cover restoration.

In Alternative 4, the contaminated sludge above the PRGs will be excavated from the WWTP site. The volume of sludge requiring remediation is estimated to be 82.5 cubic yards. Prior to excavation activities, the sludge will be sampled for analytical requirements required for disposal at an off-site facility. It is anticipated that sludge from the settling tanks will be removed using a vacuum truck and removed from the site or placed in the contained sludge drying bed. It is anticipated that excavated sludge and soils from the drying beds will be loaded directly into the dump truck with no need of on-site management. The sludge analytical data collected will be submitted to the appropriate disposal facilities for ultimate approval prior to implementation of any alternative that includes off-site disposal. It is anticipated that excavated sludge received from the WWTP site will be disposed at a Subtitle D landfill as non-hazardous waste. However, the sludge will need to be free of liquids and contain less than 10 mg/kg of total benzene, toluene, ethylbenzene, and xylenes, 50 mg/kg of PCBs, 500 mg/kg of total petroleum hydrocarbons (TPH), and will need to pass the required hazardous waste testing (Toxicity Characteristic Leaching Procedure [TCLP] and ignitability/corrosivity/reactivity [I/C/R]). Based on the RI results, it is expected that the sludge will meet these requirements.

Depending upon WWTP site conditions at the time of the remedial action, dust controls may be necessary during excavation activities to reduce the potential exposure through inhalation of particulates. Prior to excavation activities, erosion controls (i.e., silt fence) will be installed around the excavation area to prevent the contaminated sludge from migrating beyond construction areas via surface erosion and runoff. Excavated sludge will be transported to a RCRA Subtitle D landfill for disposal. Prior to WWTP site restoration activities, post-excavation confirmation sludge sampling for COPECs (chromium, mercury, DDD, and DDE) will be conducted in the excavated areas to document compliance with the sludge PRGs.

5. DETAILED ANALYSIS OF ALTERNATIVES

The detailed analysis of alternatives consists of the analysis and presentation of the relevant information needed to allow decision-makers to select a WWTP site remedy. During the detailed analysis, each alternative for the WWTP site is assessed against the NCP evaluation criteria described in Section 5.1. The results of the detailed analysis are arrayed to compare the alternatives and identify their strengths and weaknesses relative to one another. This approach to analyzing alternatives is designed to provide decision-makers with sufficient information to adequately compare the alternatives, select an appropriate remedy for the WWTP site, and demonstrate satisfaction of the CERCLA remedy selection requirements in the ROD.

CERCLA requires the review of remedial actions no less than every 5 years if the remedial action results in hazardous substances, pollutants, or contaminants remaining at the WWTP site above levels that allow for unlimited use and unrestricted exposure [40 CFR 300.430(f)(4)(ii)]. Recurring reviews for remedial actions determine whether a remedial action continues to be protective of human health, safety, and the environment, and provide an opportunity to assess the applicability of new technology for addressing previous technical impracticability determinations.

5.1 EVALUATION CRITERIA

Evaluation criteria are described in the NCP, Section 300.430. The criteria were developed to address the CERCLA requirements and considerations and to address the additional technical and policy considerations that have proven to be important in selecting remedial alternatives. These evaluation criteria serve as the basis for conducting the detailed analyses during the FFS and for subsequently selecting an appropriate remedial action. The evaluation criteria and the associated statutory considerations are described below.

The NCP calls the two criteria described below "threshold factors" because each alternative must meet the two criteria.

1. **Overall protectiveness of human health and the environment**—Determines whether an alternative achieves the RAOs by eliminating, reducing, or controlling threats to public health and the environment through LUCs, engineering controls, removal, or treatment. An emphasis is placed on effectiveness in terms of post-remedial action for local residents and workers based on future land use.
2. **Compliance with ARARs**—Evaluates whether the alternative meets federal and state environmental statutes, regulations, and other requirements that pertain to the WWTP site, or whether a waiver is justified. ARARs are summarized in Section 2.

The five “balancing factors” described below are weighed against each other to determine which remedies are cost effective and are permanent to the maximum extent practicable.

1. **Long-term effectiveness and permanence**—Considers the ability of an alternative to maintain protection of human health and the environment over time. The assessment of the long-term effectiveness and permanence of the potential remedies takes into account the mechanisms like the CERCLA five-year review process to evaluate on a periodic basis long-term effectiveness and permanence, as well as the protectiveness of the alternatives.

2. **Reduction of toxicity, mobility, or volume (TMV) of contaminants through treatment**—Evaluates an alternative's use of treatment to reduce the harmful effects of the principal contaminants, their ability to move in the environment, and the amount of contamination present.
3. **Short-term effectiveness**—Considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation.
4. **Implementability**—Considers the technical and administrative feasibility of implementing the alternative, including criteria such as the relative availability of goods and services.
5. **Cost**—includes the estimated capital and annual O&M costs, as well as present worth cost. Present worth cost is the total cost of an alternative over time in terms of today's dollar value. Thirty years is a typical period of performance to evaluate costs, but because the capital costs are presented in Year 1, the period will be extended to 31 years to capture a full five-year review period cycle. Cost estimates are expected to be accurate within a range of +50 to -30%. Costs associated with recurring reviews are included in the cost estimates presented in Section 5.2.

The last two criteria, the "modifying factors," are usually evaluated following comments on the FFS, and thus are completed after the Proposed Plan and the public comment period on the Proposed Plan:

1. **Regulatory agency acceptance**—Considers whether the state (VDEQ) and EPA Region 3 agree with the analyses and recommendations, as described in the RI/FFS.
2. **Community acceptance**—Considers whether the local community agrees with the analyses and preferred alternative. Community acceptance will be evaluated during the Proposed Plan.

5.2 ANALYSIS OF ALTERNATIVES

The evaluation of the remedial alternatives in relation to the NCP criteria is presented in Sections 5.2.1 to 5.2.4 with a summary of the evaluation provided in **Table 5-1**. The four alternatives included in the detailed analyses are as follows:

- Alternative 1 – No Action.
- Alternative 2 – Land Use Controls.
- Alternative 3 – Low-Permeability Cap Installation.
- Alternative 4 – Sludge Removal and Off-Site Disposal.

5.2.1 Alternative 1 – No Action

Alternative 1 is evaluated relative to the NCP criteria for the WWTP site as follows:

- **Overall Protectiveness of Human Health and the Environment**—Alternative 1 will not meet RAOs because there will be no reduction in sludge COPEC contaminant concentrations and no reduction in ecological receptor exposures to COPECs above PRGs. In addition, Alternative 1 will not reduce vertical contaminant migration via infiltration processes and, therefore, will not be protective of the environment. The COPECs (chromium, mercury, DDD, and DDE), however, are relatively immobile in the environment as a result of low solubility and low reactivity. Existing COPEC concentrations in sludge do not pose unacceptable risks to human health.

- **Compliance with ARARs**—There are no ARARs associated with Alternative 1 because there are no active remedial actions associated with this alternative.
- **Long-Term Effectiveness and Permanence**—Alternative 1 will not be effective in the long-term because the magnitude of risk is not expected to be reduced significantly over time. The COPECs (metals and pesticides) do not readily degrade. The long-term effectiveness of the sludge containment structure (i.e., drying bed walls) is uncertain. As a result, the potential for a release into the environment exists should there be a failure of the containment structure. Alternative 1 requires no technical components.
- **Reduction of TMV of Contaminants Through Treatment**—Alternative 1 will not address the principal threat or significantly reduce the mass, mobility, or volume of COPECs. The contaminated sludge will remain on-site. No amount of sludge will be destroyed, treated, or removed. COPECs in sludge will continue to be exposed to infiltration, although the COPECs (chromium, mercury, DDD, and DDE) are relatively immobile in the environment as a result of low solubility and low reactivity. This alternative does not address statutory preference for treatment as a principal element because the sludge is not treated.
- **Short-Term Effectiveness**—There is no additional risk to the community or workers because there are no construction or operation activities associated with Alternative 1.
- **Implementability**—Implementation of Alternative 1 poses no technical difficulties. Alternative 1 is administratively feasible because it requires minimal contact or coordination with agencies to implement.
- **Cost**—There is no action associated with Alternative 1. The total present-worth cost to perform Alternative 1 is $0.
- **Regulatory Agency Acceptance**—Regulatory acceptance will be assessed after comments on the FFS and/or Proposed Plan have been received.
- **Community Acceptance**—To be determined after conclusion of the public comment period.

5.2.2 Alternative 2 – LUCs

Alternative 2 is evaluated relative to the NCP criteria for the WWTP site as follows:

- **Overall Protectiveness of Human Health and the Environment**—LUCs (access restrictions) will be protective by restricting environmental receptors from accessing the WWTP site contaminated sludge through the use of fine mesh fence and avian netting. Existing COPEC concentrations in sludge do not pose unacceptable risks to human health. Alternative 2 will prevent the American robin and short-tailed shrew from ingesting invertebrates in direct contact with sludge concentrations above PRGs; however, Alternative 2 will not reduce vertical contaminant migration via infiltration processes. Alternative 2, therefore, will not be protective of the environment. The COPECs (chromium, inorganic mercury, DDD, and DDE), however, are relatively immobile in the environment as a result of low solubility and low reactivity. If present, methane-generating bacteria in the sludge can convert inorganic mercury to organic mobile forms (such as methyl mercury salts), which are very soluble.

- **Compliance with ARARs:**
  - *Chemical-specific ARARs*—No chemical-specific ARAR was identified for the contaminated sludge.
  - *Action-specific ARARs* - The applicable action-specific ARARs for this alternative include the substantive provisions of the Virginia Ambient Air Quality Standards, Standards of Performance for Visible Emissions and Fugitive Dust/Emissions. The construction of the fine mesh fencing may result in the generation of contaminated dust. Dust control measures (e.g., wetting the soil) will be conducted to prevent particulate matter from becoming fugitive during construction. Alternative 2 will comply with this ARAR. The substantive provisions of the Virginia Pollutant Abatement (VPA) Permit Regulation would apply to the extent that allowing the contaminated sludge to remain on-site is viewed as a form of on-site sewage sludge disposal. If so, Alternative 2 would not comply with this ARAR.
- **Long-Term Effectiveness and Permanence**—Implementation of Alternative 2 will be contingent on the cooperation and active participation of the existing powers and authorities of government agencies. The remedial design will specify steps and controls to be put in place to ensure that the fine mesh fencing and netting will be maintained, thus ensuring long-term effectiveness and permanence. Due to the low COPEC concentrations and limited volume of contaminated sludge (i.e., no more than 66 cubic yards total), the contaminated sludge poses a relatively low long-term threat. The components of LUCs require the installation and maintenance of warning signs and a fine mesh fence around and avian netting above the sludge drying beds. Alternative 2 will also require revisions to NASA's Master Plan to restrict intrusive activities within the sludge drying bed. Because the level of contaminants left in place does not allow for unlimited use/unrestricted exposure (UU/UE), WWTP site reviews and LTM will be conducted every 5 years, as required by CERCLA, to assess the WWTP site condition and the degree of protectiveness.
- **Reduction of TMV of Contaminants Through Treatment**—Alternative 2 will not reduce the volume, toxicity, or mobility of the sludge COPECs because no active remediation will take place. The COPECs (chromium, mercury, DDD, and DDE), however, are relatively immobile in the environment as a result of low solubility and low reactivity. This alternative does not meet the statutory preference for treatment.
- **Short-Term Effectiveness**—Alternative 2 will pose minimal physical hazards to workers in the short term because no heavy equipment is expected to be needed to install the fine mesh fencing and netting. Minimal dust generation is expected during fencing and netting installation. If necessary, dust control measures (e.g., watering of soils) will be employed to prevent particulate matter from becoming fugitive during installation. This alternative would be effective in the short-term as protection of environmental receptors would be achieved immediately by preventing contact with the contaminated sludge.

- **Implementability**—The components of Alternative 2 can be easily implemented because no technical difficulties are associated with this alternative. The materials and services needed to install fine mesh fencing and netting and collect and analyze samples are readily available. Provisions and legal agreements that perpetuate the LUCs will be established, as well as accountabilities for enforcement between five-year reviews. Multiple redundancies in enforcement that include contractual restrictive covenants with the property owners, as well as municipal enforcement through building development permitting requirements are preferable, but become more difficult to implement and perpetuate over time. Revisions to NASA's Master Plan are easily implemented as the property owner is knowledgeable of current documents and conditions at the WWTP site.
- **Cost**—The total present-worth cost to perform Alternative 2 is $365,000. The cost has been rounded to the nearest thousand dollars. The cost to perform Alternative 2 is summarized in **Table 5-1**. Detailed cost estimates for Alternative 2 are provided in Appendix B.

5.2.3 Alternative 3 – Low-Permeability Cap Installation

Alternative 3 is evaluated relative to the NCP criteria for the WWTP site as follows:

- **Overall Protectiveness of Human Health and the Environment**—The implementation of a 2-foot clay cap and geotextile liner over the contaminated sludge will reduce the potential for ecological receptors to access the sludge, provided the cap remains in place over time. Existing COPEC concentrations in sludge do not pose unacceptable risks to human health. Migration of COPECs and potential contact with the contaminants at the WWTP site will be controlled by the installation of the cap and geotextile liner over the contaminated sludge. The COPECs (chromium, mercury, DDD, and DDE), however, are relatively immobile in the environment as a result of low solubility and low reactivity. The geotextile liner placed under the soil cap will also prevent the potential for burrowing mammals (e.g., short-tailed shrew) to come in contact with contaminated sludge if these mammals breach the soil cap. Human access will be limited through the use of signage and providing awareness for workers/visitors to the area through brochures and handouts. RAOs will be met by Alternative 3 with the implementation of the above measures.
- **Compliance with ARARs:**
  - *Chemical-specific ARARs*—Although no chemical-specific ARAR was identified for the contaminated sludge, Alternative 3 will not comply with the PRGs for the sludge COPECs as PRG exceedances will remain on-site.
  - *Action-specific ARARs*—Action-specific ARARs applicable to Alternative 3 include the substantive provisions of the *Virginia Ambient Air Quality Standards, Standards of Performance for Visible Emissions and Fugitive Dust/Emissions*. The construction of the cap may result in the generation of contaminated dust. Fugitive dust will be limited through effective WWTP site watering during any grading or capping operations. The substantive provisions of the *Virginia Pollutant Abatement (VPA) Permit Regulation* would apply to the extent that allowing the contaminated sludge to remain on-site is viewed as a form of on-site sewage sludge disposal. If so, Alternative 3 would not comply with this ARAR.

- **Long-Term Effectiveness and Permanence**—Alternative 3 will provide long-term effectiveness and permanence. Installation of the cap will provide an effective and permanent means of eliminating potential exposure of ecological receptors to the contaminated sludge. Routine inspection and maintenance will be required to ensure that the integrity of the clay cap remains intact over time. Due to the low COPEC concentrations and limited volume of contaminated sludge (i.e., no more than 66 cubic yards total), the contaminated sludge poses a relatively low long-term threat. Because the level of contaminants left in place does not allow for UU/UE, a review of WWTP site conditions will be required every 5 years.
- **Reduction of TMV of Contaminants Through Treatment**—Alternative 3 will not reduce the sludge COPEC volume or inherent toxicity because the sludge COPECs will be left in place at the WWTP site. Installation of a clay cap and geotextile liner does not satisfy the preference for treatment as a principal element. Alternative 3 will mitigate ecological risks at the WWTP site by preventing contact with the contaminated sludge through the installation of the cap. Mobility (vertical migration) of the COPECs will be greatly reduced because the low-permeability cap and geotextile liner will prevent the infiltration of water through the sludge. The cap will also mitigate the potential for contaminant migration to adjacent soil by reducing surface erosion and runoff.
- **Short-Term Effectiveness**—Implementation of Alternative 3 will pose some level of increased risk to the community during construction and implementation. Some minimal and short term truck traffic and associated traffic hazards are anticipated as a result of trucking in clean soil from off-site sources for the low-permeability cap.

  Workers will incur the risk of injury or death while performing construction activities that involve the operation of heavy equipment. Physical hazards will be minimized by adhering to standard industry safety practices and use of personal protective equipment (PPE). Prior to construction of the cap, vertical barriers (e.g., silt fence) will be installed around the area of the contaminated sludge to minimize the potential for contaminant migration via surface erosion and runoff during alternative implementation. The vertical barriers will be removed after completion of the low-permeability cap.

  Short-term environmental impacts include those associated with the construction of vertical barriers (i.e., silt fencing) and installation of the cap. These activities could disturb the habitat of terrestrial and vegetative species at the WWTP site through potential surface erosion and runoff during soil cap installation activities. The risks to the environment from fugitive dust will be minimized by the use of dust control measures (e.g., watering of soils). Following construction, these areas will be restored to their present condition.

- **Implementability**—Capping is a proven technology that has been implemented at other sites and is often used on landfills. No technical difficulties are associated with Alternative 3 because the materials and services needed to construct the cap and install warning signs are readily available. These materials and services include locally available borrow areas to obtain soils for the cap, trucking firms to transport the soils from the borrow area to the WWTP site, an easily obtainable geotextile liner, and contractors to install the clay cap and liner. The cap can be constructed using conventional equipment. Revisions to NASA's Master Plan are easily implemented as the property owner is knowledgeable of current documents and conditions at the WWTP site.

- **Cost**—The total present-worth cost to perform Alternative 3 is $563,000. This cost has been rounded to the nearest thousand dollars. The cost to perform Alternative 3 is summarized in **Table 5-1**. Detailed cost estimates for Alternative 3 are provided in Appendix B.

5.2.4 Alternative 4 – Sludge Removal and Off-Site Disposal

Alternative 4 is evaluated relative to the NCP criteria for the WWTP site as follows:

- **Overall Protectiveness of Human Health and the Environment**—The implementation of the removal of contaminated sludge will eliminate potential ecological risks and achieve RAOs. Existing COPEC concentrations in sludge do not pose unacceptable risks to human health. Installation of vertical barriers (e.g., silt fence) to aid construction activities will minimize the potential for contaminant migration via surface erosion and runoff during alternative implementation. The vertical barriers will be removed after completion of the sludge removal and WWTP site restoration activities.

- **Compliance with ARARs:**

  - *Chemical-specific ARARs*—Although no chemical-specific ARAR was identified for the contaminated sludge, Alternative 4 will comply with the PRGs for the sludge COPECs because sludge with concentrations greater than the PRGs will be removed from the WWTP site.

  - *Action-specific ARARs*—Action-specific ARARs applicable to Alternative 4 include possible impacts to air quality during any grading and removal operations. Visible emissions discharged to the atmosphere shall be less than 20% opacity, except for one 6-minute period in any one hour of not more than 30% opacity. Failure to meet the requirements due to the presence of water vapor shall not be a violation. During the construction, reasonable precautions will be employed to prevent particulate matter from becoming airborne. Fugitive dust will be limited through effective WWTP site watering during any grading or removal operations. Compliance with RCRA and Virginia Solid Waste Management Regulations (VSWMR) during off-site transport and disposal of contaminated sludge will be ensured through the use of a U.S. Department of Transportation (DOT)-licensed transporter for hauling of materials and off-site disposal at a VDEQ-approved facility for disposal of RCRA Subtitle D waste (non-hazardous solid waste).

- **Long-Term Effectiveness and Permanence**—Alternative 4 will provide long-term effectiveness and permanence. Removal of sludge with contaminant concentrations greater than the PRGs will provide an effective and permanent means of eliminating potential exposure of ecological receptors to the contaminated sludge. Because the contaminants left at the WWTP site will be at concentrations lower than the PRGs, resulting in UU/UE, a post-excavation confirmation sludge sampling event and inspection of the ground cover restoration activities will be completed to verify conditions are stable.

- **Reduction of TMV of Contaminants Through Treatment**—Alternative 4 will reduce the sludge COPEC volume because the sludge COPECs above the PRGs will be removed from the WWTP site, even though the volume will be transferred to an off-site landfill. The toxicity of contaminants left at the WWTP site will be reduced because the contaminated sludge will be removed to an off-site location, even though without a reduction in inherent toxicity. Alternative 4 will reduce sludge contaminant mobility (although relatively immobile) at the WWTP site as the contaminated sludge will be removed to an off-site location. Sludge removal and off-site disposal would not satisfy the preference for treatment as a principal element. No treatment will be conducted for the excavated contaminated sludge because concentrations are at levels that can be accepted at a Subtitle D landfill without treatment. The threat to ecological receptors will be considered extremely low because the sludge is being removed from the WWTP site; therefore, treatment is not warranted under Alternative 4.

- **Short-Term Effectiveness**—Implementation of Alternative 4 will not pose increased risk to the community during construction and implementation because the construction area is small and the nearest residents are approximately 0.45 miles north of the WWTP site, far enough away to not be impacted. Some minor additional truck traffic and associated traffic hazards are anticipated during site activities. Workers will also incur risk of injury or death while performing construction activities involving the operation of heavy equipment. These risks will be minimized by the use of PPE and enforcement of safety procedures.

  Environmental impacts resulting from the implementation of Alternative 4 will include those associated with the construction of vertical barriers (e.g., silt fences) and sludge removal. These activities could disturb the habitat of terrestrial and vegetative species living in the WWTP site soils through potential runoff during soil excavation activities and the generation of fugitive dust. Runoff potential will be mitigated by the installation of the vertical barriers. The risks to the environment by fugitive dust will be minimized by the use of dust control measures (e.g., watering of soils). Following construction, these areas will be restored to their present condition.

- **Implementability**—Contaminant removal is a common practice and is used often for small sites such as the WWTP site. No technical difficulties are associated with Alternative 4. Most of the components in Alternative 4 are easily implemented because no technical difficulties are associated with this alternative. The materials, technology, and services needed to implement this alternative are readily available. These materials and services include analytical services, locally available borrow areas for soils for WWTP site restoration, trucking firms to transport the soils from the borrow area to the WWTP site and the excavated sludge to an off-site disposal facility, and contractors to excavate the sludge and perform associated activities.

- **Cost**—The total present-worth cost to perform Alternative 4 is $316,000. The cost has been rounded to the nearest thousand dollars. The cost to perform Alternative 4 is summarized in **Table 5-1**. Detailed cost estimates for Alternative 4 are provided in Appendix B.

SECTION 5

TABLE

Table 5-1
Evaluation of Draft Alternatives
WWTP Area, Wallops Flight Facility

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 Low-Permeability Cap Installation	Alternative 4 Sludge Removal and Off-Site Disposal
OVERALL PROTECTIVENESS				
Human Health Protection	No human health risks are present.	No human health risks are present.	No human health risks are present.	No human health risks are present.
Environmental Protection	No reduction in risk because no mitigating actions are performed.	LUCs and access restrictions (fine mesh fencing and avian netting) will reduce risks to ecological receptors from contaminated sludge by deterring direct contact and ingestion of invertebrates.	A low-permeability clay cap and geotextile liner will provide environmental protection because contact with the contaminated sludge by ecological receptors will be prevented.	Removal of contaminated sludge will eliminate ecological risks.
COMPLIANCE WITH ARARs				
Chemical-Specific ARARs	Although no chemical-specific ARARs were identified, the alternative will not achieve PRGs. Contaminated sludge above the PRGs will remain on-site.	Although no chemical-specific ARARs were identified, the alternative will not achieve PRGs. Contaminated sludge above the PRGs will remain on-site.	Although no chemical-specific ARARs were identified, the alternative will not achieve the PRGs. Contaminated sludge above the PRGs will remain on-site.	Although no chemical-specific ARARs were identified, the alternative will achieve the PRGs. Contaminated sludge will not be treated to meet PRGs; it will be removed from the WWTP site.
Action-Specific ARARs	Will achieve action-specific ARARs because no actions will be performed.	Will achieve action-specific ARARs.	Will achieve action-specific ARARs.	Will achieve action-specific ARARs.

Table 5-1
Evaluation of Draft Alternatives
WWTP Area, Wallops Flight Facility (Continued)

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 Low-Permeability Cap Installation	Alternative 4 Sludge Removal and Off-Site Disposal
LONG-TERM EFFECTIVENESS AND PERMANENCE				
Magnitude of Residual Risk	Contaminated sludge will not be removed and existing risks will remain.	LUCs and access restrictions (fine mesh fencing and avian netting) will minimize the potential for ecological receptors to contact the sludge.	Risks currently associated with the contaminated sludge will be reduced through sludge cap installation because contact with the contaminated sludge is highly unlikely.	Ecological risks currently associated with the contaminated sludge will be eliminated.
Adequacy and Reliability of Controls	No controls over remaining contamination will be implemented.	LUCs and access restrictions will deter human receptors. Fine mesh fencing and avian netting will deter ecological receptors.	Installation of low-permeability cap and geotextile liner will be an adequate and reliable control to reduce the potential ecological risk because it will provide a barrier to ecological receptors, including burrowing mammals such as the short-tailed shrew.	Removal of sludge above PRGs will provide an effective and permanent means of eliminating potential exposure of ecological receptors to the contaminated sludge.
Need for Five-Year Review	No five-year review will be conducted for this alternative.	A five-year review will be required because contaminants above PRGs will be left on-site. LTM will be required to ensure adequate protection of the environment is maintained.	A five-year review will be required to ensure adequate protection of the environment is maintained through use of the low-permeability cap. A five-year review will be required because contaminants above PRGs will be left on-site.	No contaminants above PRGs will be left on-site. Five-year review will not be required.

Table 5-1
Evaluation of Draft Alternatives
WWTP Area, Wallops Flight Facility (Continued)

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 Low-Permeability Cap Installation	Alternative 4 Sludge Removal and Off-Site Disposal
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT				
Treatment Process Used	None	None	None	None
Reduction of Toxicity, Mobility, or Volume	TMV will not be reduced.	Inherent toxicity will not be reduced. Risks to ecological receptors via direct contact will be reduced. Mobility and volume of COPECs will not be reduced.	Mobility will be reduced; however, toxicity and volume will not be reduced.	TMV at the WWTP site will be reduced because sludge COPECs above PRGs will not remain on-site. The inherent toxicity and volume of the contaminated sludge will not be reduced because the sludge will be transferred to an off-site disposal facility
Type and Quantity of Residuals Remaining After Treatment	Sludge COPECs above PRGs will remain on-site.	Sludge COPECs above PRGs will remain on-site.	Sludge COPECs above PRGs will remain on-site.	Sludge COPECs above PRGs will not remain on-site.
SHORT-TERM EFFECTIVENESS				
Community Protection	No additional risks posed to the community.	No additional risks to the community during fencing and netting installation.	Minimal additional risks to the community during low-permeability cap construction.	Minimal additional risk to the community during sludge removal and transport off-site.
Worker Protection	Not applicable	Potential risks to workers during fencing and netting installation will be minimized by use of dust control measures, PPE, and safety procedures.	Potential risks to workers during grading and low-permeability clay cap installation will be minimized by use of dust control measures, PPE, and safety procedures.	Potential risks to workers during sludge removal and WWTP site restoration will be minimized by use of dust control measures, PPE, and safety procedures.

Table 5-1
Evaluation of Draft Alternatives
WWTP Area, Wallops Flight Facility (Continued)

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 Low-Permeability Cap Installation	Alternative 4 Sludge Removal and Off-Site Disposal
Environmental Impacts	No additional risk but continued impact from existing conditions.	Protection of environmental receptors achieved immediately by preventing contact with the contaminated sludge.	Areas affected during remedial operations will be restored.	Areas affected during remedial operations will be regraded and revegetated.
IMPLEMENTABILITY				
Ability to Construct and Operate	No construction or operation.	Materials and services needed to install fencing and netting are readily available.	Materials and services required to implement construction of a low-permeability clay cap and geotextile liner are readily available.	Materials and services required to implement sludge removal and off-site disposal are readily available.
Ability to Monitor Effectiveness	No monitoring will be conducted.	Revisions to NASA's Master Plan easily implemented because property owner is knowledgeable of current documents and conditions.	Effectiveness of the low-permeability cap can be monitored through periodic WWTP site inspections.	Post-removal monitoring not required. Effectiveness of the post-removal vegetative cover in preventing erosion can be easily implemented.
Availability of Services and Capacities	No services or capacities required.	Materials, equipment, and services required to implement Alternative 2 are readily available.	Materials, equipment, and services required to implement Alternative 3 are readily available.	Materials, equipment, and services required to implement Alternative 4 are readily available.

Table 5-1
Evaluation of Draft Alternatives
WWTP Area, Wallops Flight Facility (Continued)

Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 Low-Permeability Cap Installation	Alternative 4 Sludge Removal and Off-Site Disposal
Availability of Equipment, Specialists, and Materials	None required.	Equipment, specialists, and materials required to implement Alternative 2 are readily available.	Equipment, specialists, and materials required to implement Alternative 3 are readily available.	Equipment, specialists, and materials required to implement Alternative 4 are readily available.
Availability of Technologies	None required.	Avian netting and fine mesh fencing are readily available from a large number of vendors.	Low-permeability cap is a proven technology that has been implemented at other sites and is often used on landfills.	Contaminant removal is a common practice and often used for small sites such as the WWTP site.
COST ESTIMATE (rounded to nearest $1,000)				
Capital Cost	$ -	$117,000	$305,000	$316,000
First Annual O&M Cost	$ -	$50,000	$44,000	$0
Present Worth Cost	$ -	$365,000	$563,000	$316,000

6. COMPARATIVE ANALYSIS OF ALTERNATIVES

In the following analysis, the remedial alternatives are evaluated in relation to one another for each of the seven criteria evaluated in Section 5. The purpose of the analysis is to identify the relative advantages and disadvantages of each alternative and to provide a scoring analysis of each alternative. **Table 6-1** presents a summary of the analysis, which includes a numerical ranking system of 1 through 5 (1 being the highest ranked alternative and 5 being the lowest) to provide a quantitative evaluation of the following four alternatives:

- Alternative No. 1 – No Action
- Alternative No. 2 – Land Use Controls
- Alternative No. 3 – Low-Permeability Cap Installation
- Alternative No. 4 – Sludge Removal and Off-Site Disposal

6.1 COMPARATIVE ANALYSIS

6.1.1 Protection of Human Health and Environment

Existing COPEC concentrations in sludge do not pose unacceptable risks to human health Alternative 1 will not protect the environment because no reduction in sludge COPEC contaminant concentrations and no reduction in ecological receptor exposures will occur. Alternatives 2, 3, and 4 are the more protective of the environment because they will provide some level of protection to ecological receptors from short-term and long-term risks associated with the WWTP site contaminated sludge. Alternative 2 will be protective by restricting environmental receptors from accessing the WWTP site contaminated sludge. COPECs will remain on-site. Alternative 2 will not reduce vertical contaminant migration via infiltration processes and, therefore, will not be protective of the environment. Alternative 3 will reduce the potential for ecological receptors to access the sludge, provided the integrity of the cap is maintained. COPECs will remain on-site. Migration of COPECs and potential contact with the contaminants will be controlled by the installation of the cap and geotextile liner. Under Alternative 4 contaminated sludge above the PRGs will be removed, thus eliminating the potential ecological risks.

6.1.2 Compliance with ARARs

No chemical-specific ARARs were identified for the WWTP site. Alternative 4 will remove sludge above the PRGs. Ecological receptors will not be in contact with sludge having COPEC concentrations greater than the PRGs because the sludge will be removed from the WWTP site. There are no ARARs to comply with for Alternative 1 because there are no remedial actions associated with this alternative. Alternatives 2, 3, and 4 will comply with action-specific ARARs. However, the substantive provisions of the *VPA Permit Regulation* would apply to the extent that allowing the contaminated sludge to remain on-site is viewed as a form of on-site sewage sludge disposal. If so, Alternative 2 would not comply with this ARAR. Under Alternatives 1, 2, and 3, COPECs will remain on-site above PRGs. Alternative 4 will attain PRGs because the sludge above PRGs will be removed.

6.1.3 Long-Term Effectiveness and Permanence

Alternative 4 will provide the greatest long-term effectiveness because potential risks to ecological receptors will be eliminated by the removal of COPECs above PRGs. Alternative 3 is less effective than Alternative 4 because COPECs above PRGs will remain on-site and the effectiveness of Alternative 3 is a function of maintaining the integrity of the low-permeability cap. Alternative 2 will be less effective than Alternatives 3 and 4 because the installation of avian netting and fine mesh fencing may only minimize direct contact of ecological receptors with COPECs above PRGs. As with Alternative 3, the effectiveness of Alternative 2 is a function of maintaining the integrity of the netting and fencing. Alternative 1 has the lowest long-term effectiveness and permanence because no action is taken. Only Alternative 4 will provide unrestricted land use because the contaminated sludge above the PRGs will be removed from the former WWTP site.

6.1.4 Reduction of Toxicity, Mobility, and Volume

Alternative 4 is most effective at meeting this criterion. Alternative 4 is the only alternative that will reduce TMV at the WWTP site by removing contaminated sludge above PRGs. The inherent toxicity and volume of COPECs remain but will be transferred to an off-site landfill. Alternatives 1 and 2 will not reduce TMV because no active remediation will take place. Alternative 3 will not reduce toxicity or volume, but it will reduce mobility. The installation of a low-permeability cap and geotextile liner will reduce the infiltration of water through the contaminated sludge. None of the alternatives satisfy the preference for treatment as a principal element.

6.1.5 Short-Term Effectiveness

Alternative 1 is most effective in the short term because there will be no additional risk to the community or workers. Alternative 2 has fewer short-term impacts than all alternatives except Alternative 1 because of fewer invasive activities. Alternatives 3 and 4 will have minor short-term impacts on-site during implementation. These impacts, however, will be addressed by using standard work practices, safety measures, and dust control measures. Alternative 3 will involve more truck traffic and its associated physical hazards than Alternative 4 because the volume of clay needed for the low-permeability cap is greater than the volume of contaminated soil to be transported off-site under Alternative 4. These hazards will be mitigated by using standard work practices and safety measures. The increased truck traffic under both Alternatives 3 and 4 will not be concentrated in a manner that will significantly impact local traffic patterns. Although Alternative 3 involves more truck traffic than Alternative 4, only non-contaminated materials will be transported under Alternative 3.

6.1.6 Implementability

Alternatives 3 and 4 are less easily implemented than Alternatives 1 and 2 because they require more difficult and complex construction-related activities and operations. Alternative 1 is the easiest to implement because it requires no action. Alternative 2 is the most implementable of the alternatives that include an action because it involves only LUCs and fine mesh fencing, avian netting, and sign installation. Revisions to NASA's Master Plan are easily implemented as the property owner is knowledgeable of current documents and conditions at the WWTP site. The low-permeability cap in Alternative 3 is a proven technology that has been implemented at other sites and is often used on landfills. Contaminant removal in Alternative 4 is a common practice and is used often for small sites such as the WWTP site. No technical difficulties are associated with either Alternative 3 or 4. There is little difference in the implementability of Alternatives 3 and 4, although implementation of Alternative 3 requires the transport of more materials and potentially a larger construction area.

6.1.7 Cost

Alternative 1 involves no action; therefore, no cost is associated with this alternative. Alternative 3 is the most costly with a present net worth (PNW) of approximately $563,000. Alternative 2 has a PNW of $365,000 and is less costly than Alternative 3 but more costly than Alternative 4. The PNW of Alternative 4 is estimated at $316,000.

6.1.8 State and Community Acceptance

As noted in Section 5, state and community acceptances are not evaluated in the FFS. State acceptance will be addressed by VDEQ review and comment on the FFS and Proposed Plan. Community acceptance will be addressed during the Proposed Plan comment period and associated public meeting. State and community acceptance will be addressed in the ROD once formal comments on the Proposed Plan have been received and a final remedy selection decision is being made.

6.2 SUMMARY

Alternative 1 does not meet the threshold criteria. Alternative 2 provides adequate protection of ecological receptors but only through the access controls of fine mesh fencing and avian netting. COPECs above PRGs will remain on-site. Alternative 3 is more protective of ecological receptors than Alternative 2, but COPECs above PRGs will also remain on-site under Alternative 3. Alternative 4 is the most protective of ecological receptors because contaminated sludge with COPECs above PRGs will be removed. Therefore, Alternative 4 will provide a permanent solution that will remain effective over time. Both Alternatives 2 and 3 require ongoing maintenance to remain effective. Alternative 3 will require more extensive maintenance. Alternative 3 involves the greatest degree of short-term physical hazards to on-site workers and the community due to the amount of truck traffic associated with transporting capping materials to the WWTP site. A lesser degree of short-term physical hazards to on-site workers and the community would be posed by Alternative 4 due to the lesser volume of materials requiring transport. Of the two alternatives (Alternatives 3 and 4) that reduce potential ecological risks to acceptable levels upon implementation, Alternative 4 is the most cost-effective because it is over $200,000 less than Alternative 3 while providing a greater level of protection to potential ecological receptors and providing for unrestricted land use and unlimited exposure.

SECTION 6

TABLE

Table 6-1
Summary of Alternatives Evaluation
WWTP Area, Wallops Flight Facility

Evaluation Criteria	Alternative 1 No Action	Alternative 2 Land Use Controls	Alternative 3 Low-Permeability Cap Installation	Alternative 4 Sludge Removal and Off-Site Disposal
Overall protection of human health and the environment	4	3	2	1
Compliance with ARARs	4	3	2	1
Long-term effectiveness and permanence	4	3	2	1
Reduces toxicity, mobility, or volume	4	3	2	1
Short-term effectiveness	1	2	4	3
Implementability	1	2	4	3
Cost	1	3	4	2

Notes:

1 - Highest ranking alternative.

4 - Lowest ranking alternative.

7. REFERENCES

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APPENDIX A

FOOD CHAIN HQ MODELING OF SLUDGE COPECs

Table A-1
Small Mammal Bioaccumulation Factors Calculated Using Data Collected from Sites 14 and 15
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia

Compound (1)	Maximum Surface Soil (0-0.5 ft) Concentration at Site 14 (2)	Maximum Surface Soil (0-0.5 ft) Concentration at Site 15 (3)	Max of Both Sites 14 and 15	Maximum Small Mammal Concentration at Site 14 (4)	Maximum Small Mammal Concentration at Site 15 (5)	Max of Both Sites 14 and 15	Small Mammal BAF *
Organic Compounds (mg/kg)							
4,4-DDD	8.70E-03	1.20E-01	1.20E-01	ND	ND	ND	1.00E+00
4,4-DDE	2.30E-01	1.00E+00	1.00E+00	1.10E+00	2.40E+00	2.40E+00	2.40E+00
4,4-DDT	1.40E-01	1.80E+00	1.80E+00	2.00E-01	2.70E-01	2.70E-01	1.50E-01
Dieldrin	ND	ND	ND	ND	ND	ND	1.00E+00
Inorganics (mg/kg)							
Aluminum	8.99E+03	7.60E+03	8.99E+03	4.93E+01	7.59E+01	7.59E+01	8.44E-03
Antimony	9.90E-01	5.00E+00	5.00E+00	2.40E-01	2.40E-01	2.40E-01	4.80E-02
Cadmium	4.10E-01	1.50E+00	1.50E+00	8.80E-01	7.10E-01	8.80E-01	5.87E-01
Chromium	8.70E+00	9.70E+00	9.70E+00	ND	ND	0.00E+00	1.00E+00
Copper	5.90E+01	3.19E+01	5.90E+01	4.70E+00	4.70E+00	4.70E+00	7.97E-02
Iron	7.99E+03	9.41E+03	9.41E+03	1.42E+02	1.70E+02	1.70E+02	1.81E-02
Lead	2.95E+01	1.10E+02	1.10E+02	ND	3.50E+00	3.50E+00	3.18E-02
Manganese	2.89E+02	4.09E+02	4.09E+02	6.20E+00	3.60E+00	6.20E+00	1.52E-02
Mercury	5.00E-02	2.20E-01	2.20E-01	1.40E-01	3.20E-01	3.20E-01	1.45E+00
Silver	ND	2.90E+00	2.90E+00	ND	6.50E-02	6.50E-02	2.24E-02
Vanadium	1.87E+01	2.39E+01	2.39E+01	4.00E-01	3.90E-01	4.00E-01	1.67E-02
Zinc	9.36E+01	1.55E+02	1.55E+02	3.39E+01	3.77E+01	3.77E+01	2.43E-01

Notes:

BAF = Bioaccumulation factor

ND = Not detected in soil samples

* BAFs were assumed to be 1.0 for those compounds where either the tissue or soil concentration was not detected.

(1) Chemical list includes those chemicals whose maximum concentration in WWTP sludge exceeded the ecological benchmark, chemicals for which ecological benchmarks were not available, and bioaccumulative compounds. Refer to Table 8-6 of the RI (WESTON, 2011).

(2) Table 7-2, Sites 14 and 15 RI (WESTON, 2011)

(3) Table 7-3, Sites 14 and 15 RI (WESTON, 2011)

(4) Table 7-6, Sites 14 and 15 RI (WESTON, 2011)

(5) Table 7-7, Sites 14 and 15 RI (WESTON, 2011)

Table A-2
Comparison of WWTP Soil and Sludge Data with Reference Background Concentrations
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia
(only those constituents exceeding ecological benchmarks are included in comparison)

Chemical	Site Soil - Range of Detected Concentrations	Site Soil - Arithmetic Mean	Site Sludge- Range of Detected Concentrations	Site Sludge - Arithmetic Mean	Background - Range of Detected Concentrations[a]	Background - Arithmetic Mean[a]	Background - 95%UTL[a]
INORGANICS (mg/kg)							
Aluminum, Total	1400 - 13000	7396	680 - 6900	4460	1870 - 13900	9460	21800
Antimony, Total	0.54 - 3.2	1.8	12 - 20	16	NC	NC	NC
Cadmium, Total	0.29 - 0.37	0.332	2.2 - 3.7	2.95	0.11 - 0.84	0.209	NC
Chromium, Total	NA	NA	36 - 65	50.5	1.9 - 18.4	9.57	23.3
Copper, Total	NA	NA	11 - 180	123.7	2.1 - 33	8.91	82.8
Iron, Total	2500 - 10000	5278.3	12000 - 15000	13667	1740 - 10900	7590	16300
Lead, Total	2.2 - 460	60.1	130 - 530	340	4.9 - 124	30.6	NC
Manganese, Total	9.5 - 320	90.4	160 - 270	206.7	8.4 - 781	368	1060
Mercury, Total	0.0046 - 0.25	0.055	0.17 - 28	17.39	0.025 - 0.25	0.0688	0.675
Silver, Total	NA	NA	110 - 130	120	0.15 - 0.3	0.112	NC
Vanadium, Total	2.4 - 24	12.9	7.2 - 18	13.7	3.5 - 28.5	16.9	39.6
Zinc, Total	6.8 - 250	57.1	420 - 680	513.3	4.5 - 104	29.4	247
PESTICIDES (µg/kg)							
4,4'-DDD	NA	NA	110 - 1200	803.3	NC	NC	NC
4,4'-DDE	NA	NA	67 - 1400	922.3	5.7 - 5000	539	NC
4,4'-DDT	0.79 - 43	15.7	110 - 1100	700	4.2 - 15000	1560	NC
Dieldrin	3.9 - 5.7	4.8	5.6 - 9.9	7.75	NC	NC	NC
PCBs (µg/kg)							
Aroclor-1260	190 - 290	256.7	NA	NA	NC	NC	NC
SVOCs (µg/kg)							
Anthracene	NA	NA	64 - 630	256	NC	NC	NC
Benzo[a]anthracene	NA	NA	290 - 2100	0.93	550 - 550	237	NC
Benzo[a]pyrene	NA	NA	290 - 910	0.563	46 - 410	206	NC
Benzo[b]fluoranthene	NA	NA	550 - 4800	2.073	76 - 640	232	NC
Benzo[g,h,i]perylene	NA	NA	270 - 1200	620	NC	NC	NC
Benzo[k]fluoranthene	NA	NA	290 - 2400	1.093	290 - 290	211	NC
Chrysene	NA	NA	480 - 4700	1916.7	67 - 630	230	NC
Fluoranthene	NA	NA	410 - 9000	3303	87 - 1000	269	NC
Fluorene	NA	NA	360 - 360	360	NC	NC	NC
Indeno[1,2,3-cd]pyrene	NA	NA	230 - 1400	0.653	NC	NC	NC
Phenanthrene	NA	NA	170 - 3000	1123.3	790 - 790	261	NC
Pyrene	NA	NA	360 - 6300	2360	120 - 890	261	NC
VOCs (µg/kg)							
Toluene	NA	NA	6.2 - 1200	603.1	NC	NC	NC

Notes:
(light shading) Detected concentrations exceed the background range.
(dark shading) Background concentrations not available for this chemical. Note that PCBs were not included in the background evaluation.
mg/kg = milligram per kilogram
NA = Not applicable, chemical did not exceed benchmark for this media.
NC = Not calculated
µg/kg = microgram per kilogram
UTL = upper tolerance limit
[a] Molena Soils Data (Table 4.24) from NASA Wallops Flight Facility Background Report for the Main Base.

Table A-3
Occurrence, Distribution, and Selection of Chemicals of Potential Ecological Concern
Former Wastewater Treatment Plant Sludge
Wallops Flight Facility, Virginia

CAS Number	Analyte	Number of Samples Analyzed[1]	Number of Detected Samples	Minimum Detected Concentration	Maximum Detected Concentration [1]	Location of Maximum	Upper Depth of Maximum (feet)	Lower Depth of Maximum (feet)	Ecological Screening Benchmark										Final Screening Benchmark	No. Samples Exceeding Benchmark
									ECO-SSL[2]				ORNL[3,4,5]				BTAG			
									Avian	Invertebrate	Mammalian	Plant	Invertebrate	Microbe	Plant	Wildlife	Flora	Fauna		
	INORGANICS (mg/kg)																			
7429-90-5	Aluminum, Total	3	3	680	6900	WFF1-SL03	0	2	NA	NA	NA	NA	NA	6.00E+02	5.00E+01	NA	1.00E+00	NA	1.00E+00	3
7440-36-0	Antimony, Total	3	2	12	20	WFF1-SL02	0	2	NA	7.80E+01	2.70E-01	NA	NA	NA	5.00E+00	NA	4.80E-01	NA	2.70E-01	2
7440-38-2	Arsenic, Total	3	2	2.6	3.2	WFF1-SL03	0	2	4.30E+01	NA	4.60E+01	1.80E+01	6.00E+01	1.00E+02	1.00E+01	9.90E+00	3.28E+02	NA	1.80E+01	0
7440-39-3	Barium, Total	3	3	130	270	WFF1-SL03	0	2	NA	3.30E+02	2.00E+03	NA	NA	3.00E+03	5.00E+02	2.83E+02	4.40E+02	4.40E+02	3.30E+02	0
7440-41-7	Beryllium, Total	3	2	0.36	0.46	WFF1-SL03	0	2	NA	4.00E+01	2.10E+01	NA	NA	NA	1.00E+01	NA	2.00E-02	NA	2.10E+01	0
7440-43-9	Cadmium, Total	3	2	2.2	3.7	WFF1-SL03	0	2	7.70E-01	1.40E+02	3.60E-01	3.20E+01	2.00E+01	2.00E+01	4.00E+00	4.20E+00	2.50E+00	NA	3.60E-01	2
7440-70-2	Calcium, Total	3	3	3900	13000	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
7440-47-3	Chromium, Total	3	2	36	65	WFF1-SL02	0	2	2.60E+01	NA	3.40E+01	NA	4.00E-01	1.00E+01	1.00E+00	1.61E+01	2.00E-02	7.50E-03	2.60E+01	2
7440-48-4	Cobalt, Total	3	2	2	2.6	WFF1-SL03	0	2	1.20E+02	NA	2.30E+02	1.30E+01	NA	1.00E+03	2.00E+01	NA	1.00E+02	2.00E+02	1.30E+01	0
7440-50-8	Copper, Total	3	3	11	180	WFF1-SL03	0	2	2.80E+01	8.00E+01	4.90E+01	7.00E+01	5.00E+01	1.00E+02	1.00E+02	3.70E+02	1.50E+01	NA	2.80E+01	1
57-12-5	Cyanide, Total	3	2	1.5	1.5	WFF1-SL03	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
7439-89-6	Iron, Total	3	3	12000	15000	WFF1-SL01	0	2	NA	NA	NA	NA	NA	2.00E+02	NA	NA	3.26E+03	1.20E+01	1.20E+01	3
7439-92-1	Lead, Total	3	3	130	530	WFF1-SL02	0	2	1.10E+01	1.70E+03	5.60E+01	1.20E+02	5.00E+02	9.00E+02	5.00E+01	4.05E+01	2.00E+00	1.00E-02	1.10E+01	3
7439-95-4	Magnesium, Total	3	3	730	950	WFF1-SL03	0	2	NA	NA	NA	NA	NA	NA	NA	NA	4.40E+03	4.40E+03	4.40E+03	0
7439-96-5	Manganese, Total	3	3	160	270	WFF1-SL01	0	2	4.30E+03	4.50E+02	4.00E+03	2.20E+02	NA	1.00E+02	5.00E+02	NA	3.30E+02	3.30E+02	2.20E+02	1
7439-97-6	Mercury, Total	3	3	0.17	28	WFF1-SL03	0	2	NA	NA	NA	NA	1.00E-01	3.00E+01	3.00E-01	5.10E-04	5.80E-02	5.80E-02	5.10E-04	3
7440-02-0	Nickel, Total	3	3	4	8.9	WFF1-SL03	0	2	2.10E+02	2.80E+02	1.30E+02	3.80E+01	2.00E+02	9.00E+01	3.00E+01	1.21E+02	2.00E+00	NA	3.80E+01	0
7440-09-7	Potassium, Total	3	3	640	1300	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
7782-49-2	Selenium, Total	3	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7440-22-4	Silver, Total	3	2	110	130	WFF1-SL02	0	2	4.20E+00	NA	1.40E+01	5.60E+02	NA	5.00E+01	2.00E+00	NA	9.80E-06	NA	4.20E+00	2
7440-23-5	Sodium, Total	3	3	130	680	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
7440-28-0	Thallium, Total	3	0	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
7440-62-2	Vanadium, Total	3	3	7.2	18	WFF1-SL03	0	2	7.80E+00	NA	2.80E+02	NA	NA	2.00E+01	2.00E+00	5.50E+01	5.00E-01	5.80E+01	7.80E+00	2
7440-66-6	Zinc, Total	3	3	420	680	WFF1-SL01	0	2	4.60E+01	1.20E+02	7.90E+01	1.60E+02	1.00E+02	1.00E+02	5.00E+01	8.50E+00	1.00E+01	NA	4.60E+01	3
	PESTICIDES (µg/kg)																			
72-54-8	4,4'-DDD	3	3	110	1200	WFF1-SL03	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
72-55-9	4,4'-DDE	3	3	67	1400	WFF1-SL02	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	2
50-29-3	4,4'-DDT	3	3	110	1100	WFF1-SL03	0	2	9.30E+01	NA	2.10E+01	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	2.10E+01	3
60-57-1	Dieldrin	3	2	5.6	9.9	WFF1-SL02	0	2	2.20E+01	NA	4.90E+00	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	4.90E+00	2
	PCBS (µg/kg)																			
	Not Detected																			
	SVOCS (µg/kg)																			
106-46-7	1,4-Dichlorobenzene	3	2	84	84	WFF1-SL03	0	2	NA	NA	NA	NA	2.00E+04	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	0
120-12-7	Anthracene	3	3	64	630	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	1
56-55-3	Benzo[a]anthracene	3	3	290	2100	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
50-32-8	Benzo[a]pyrene	3	3	290	910	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
205-99-2	Benzo[b]fluoranthene	3	3	550	4800	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
191-24-2	Benzo[g,h,i]perylene	3	3	270	1200	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
207-08-9	Benzo[k]fluoranthene	3	3	290	2400	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
117-81-7	Bis(2-ethylhexyl) phthalate	3	1	79	79	WFF1-SL02	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
86-74-8	Carbazole	3	1	53	53	WFF1-SL02	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
218-01-9	Chrysene	3	3	480	4700	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
53-70-3	Dibenz(a,h)anthracene	3	1	76	76	WFF1-SL03	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	0
84-74-2	Di-n-butyl phthalate	3	2	89	110	WFF1-SL02	0	2	NA	NA	NA	NA	NA	NA	2.00E+05	NA	NA	NA	2.00E+05	0
206-44-0	Fluoranthene	3	3	410	9000	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
86-73-7	Fluorene	3	1	360	360	WFF1-SL01	0	2	NA	NA	NA	NA	3.00E+04	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	1
193-39-5	Indeno[1,2,3-cd]pyrene	3	3	230	1400	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
85-01-8	Phenanthrene	3	3	170	3000	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
129-00-0	Pyrene	3	3	360	6300	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	1.00E+02	1.00E+02	1.00E+02	3
	VOCS (µg/kg)																			
79-34-5	1,1,2,2-Tetrachloroethane	3	1	29	29	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
591-78-6	2-Hexanone	3	1	130	130	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
67-64-1	Acetone	3	3	55	740	WFF1-SL02	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
78-93-3	Methyl Ethyl Ketone	3	2	77	210	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
108-10-1	Methyl isobutyl ketone	3	1	91	91	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	--
127-18-4	Tetrachloroethene	3	1	5.1	5.1	WFF1-SL02	0	2	NA	NA	NA	NA	NA	NA	NA	NA	3.00E+02	3.00E+02	3.00E+02	0
108-88-3	Toluene	3	2	6.2	1200	WFF1-SL01	0	2	NA	NA	NA	NA	NA	NA	2.00E+05	NA	1.00E+02	1.00E+02	1.00E+02	1

Notes:

Maximum concentrations for shaded chemicals exceed screening benchmark.

BTAG - Biological Technological Assistant Group

CAS = Chemical Abstracts Service

mg/kg = milligram per kilogram

NA = Not available

PCBs = Polychlorinated biphenyls

µg/kg = microgram per kilogram

SVOCs = Semivolatile organic compounds

VOCS = Volatile organic compounds

[1] Maximum detected concentration used for screening.

[2] EPA Ecological Soil Screening Levels (ECO-SSL) (http://www.epa.gov/ecotox/ecossl/).

[3] Oak Ridge National Laboratory (ORNL). Efroymson, R.A., M.E. Will, and G.W. Suter II. 1997. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision. ORNL. ES/ER/TM-126/R2. November.

[4] ORNL. Efroymson, R.A., M.E. Will, G.W. Suter II, and A.C. Wooten. 1997. Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision. ORNL. ES/ER/TM-85/R3. November.

[5] ORNL. Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones. 1997. Preliminary Remediation Goals for Ecological Endpoints. ORNL. ES/ER/TM-162/R2. August.

Table A-4
Hazard Quotient and Preliminary Remediation Goal Summary for Terrestrial Receptors
Sludge
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia

Contaminant	Red Fox LOAEL HQ	Red-tailed Hawk LOAEL HQ	American Robin LOAEL HQ	Short-tailed Shrew LOAEL HQ	PRG mg/kg
Metals					
Aluminum, Total	2.0E-05	1.9E-05	1.1E-01	3.3E-02	NC
Antimony, Total	5.0E-06	NC	NC	8.5E-03	NC
Cadmium, Total	7.9E-07	1.6E-06	8.9E-03	1.3E-03	NC
Chromium, Total	1.7E-05	1.9E-04	1.1E+00	1.5E-02	6.11E+01
Copper, Total	2.5E-06	3.4E-06	1.9E-02	4.7E-03	NC
Iron, Total	NC	NC	NC	NC	NC
Lead, Total	7.4E-07	2.2E-05	1.2E-01	1.3E-03	NC
Manganese, Total	5.1E-08	6.1E-08	3.4E-04	8.6E-05	NC
Mercury, Total	4.4E-03	9.4E-03	5.2E+01	1.5E+00	5.38E-01
Silver, Total	NC	NC	NC	NC	NC
Vanadium, Total	5.4E-07	3.9E-07	2.2E-04	9.3E-04	NC
Zinc, Total	1.2E-06	1.9E-05	1.0E-01	3.1E-03	NC
Pesticides					
4,4'-DDD	1.1E-06	6.4E-04	3.5E+00	1.8E-03	3.42E-01
4,4'-DDE	3.0E-06	1.8E-03	9.8E+00	5.0E-03	1.43E-01
4,4'-DDT	1.4E-07	8.7E-05	4.8E-01	2.5E-04	NC
Dieldrin	1.7E-07	1.9E-06	1.1E-02	3.0E-04	NC
Polynuclear Aromatic Hydrocarbons (PAHs)					
Total LMW PAHs	1.3E-06	6.7E-07	3.7E-03	8.9E-03	NC
Total HMW PAHs	1.9E-08	2.4E-08	1.3E-04	1.4E-04	NC
Volatile Organic Compounds (VOCs)					
Toluene	2.2E-06	NC	NC	3.7E-03	NC

Notes:

Shaded area indicates an exceedance of an HQ of 1.

HQ = Hazard Quotient (Dose/LOAEL or NOAEL).

LOAEL = Lowest Observed Adverse Effect Level (Sample, 1996).

mg/kg = milligrams per kilogram.

NC = Not Calculated

NOAEL = No Observed Adverse Effect Level (Sample, 1996).

PRG = Preliminary Remediation Goal

Table A-5
Hazard Quotient Calculations for the Red Fox (LOAEL)
Sludge
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia

Contaminant	Exposure Point Concentration [1] (mg/kg)	BAF	Predicted Small Mammal Concentration [2] (mg/kg)	FIR [3] (kg/day)	HR [4] (acres)	AOC (acres)	AUF	Body Weight [5] (kg)	Dose (mg/kg BW/day)	LOAEL (mg/kg BW/day)	HQ
Metals											
Aluminum, Total	6.90E+03	8.44E-03	5.83E+01	0.432	1727.26	0.02	0.00001	2.7	1.08E-04	5.515	2.0E-05
Antimony, Total	2.00E+01	4.80E-02	9.60E-01	0.432	1727.26	0.02	0.00001	2.7	1.78E-06	0.357	5.0E-06
Cadmium, Total	3.70E+00	5.87E-01	2.17E+00	0.432	1727.26	0.02	0.00001	2.7	4.02E-06	5.094	7.9E-07
Chromium, Total	6.50E+01	1.00E+00	6.50E+01	0.432	1727.26	0.02	0.00001	2.7	1.20E-04	6.94	1.7E-05
Copper, Total	1.80E+02	7.97E-02	1.43E+01	0.432	1727.26	0.02	0.00001	2.7	2.66E-05	10.6	2.5E-06
Iron, Total	1.50E+04	1.81E-02	2.71E+02	0.432	1727.26	0.02	0.00001	2.7	5.02E-04	NA	NC
Lead, Total	5.30E+02	3.18E-02	1.69E+01	0.432	1727.26	0.02	0.00001	2.7	3.12E-05	42.25	7.4E-07
Manganese, Total	2.70E+02	1.52E-02	4.09E+00	0.432	1727.26	0.02	0.00001	2.7	7.58E-06	150	5.1E-08
Mercury, Total	2.80E+01	1.45E+00	4.07E+01	0.432	1727.26	0.02	0.00001	2.7	7.55E-05	0.017	4.4E-03
Silver, Total	1.30E+02	2.24E-02	2.91E+00	0.432	1727.26	0.02	0.00001	2.7	5.40E-06	NA	NC
Vanadium, Total	1.80E+01	1.67E-02	3.01E-01	0.432	1727.26	0.02	0.00001	2.7	5.58E-07	1.03	5.4E-07
Zinc, Total	6.80E+02	2.43E-01	1.65E+02	0.432	1727.26	0.02	0.00001	2.7	3.06E-04	250	1.2E-06
Pesticides											
4,4'-DDD	1.20E+00	1.00E+00	1.20E+00	0.432	1727.26	0.02	0.00001	2.7	2.22E-06	2.11	1.1E-06
4,4'-DDE	1.40E+00	2.40E+00	3.36E+00	0.432	1727.26	0.02	0.00001	2.7	6.22E-06	2.11	3.0E-06
4,4'-DDT	1.10E+00	1.50E-01	1.65E-01	0.432	1727.26	0.02	0.00001	2.7	3.06E-07	2.11	1.4E-07
Dieldrin	9.90E-03	1.00E+00	9.90E-03	0.432	1727.26	0.02	0.00001	2.7	1.83E-08	0.106	1.7E-07
Polynuclear Aromatic Hydrocarbons (PAHs)											
Total LMW PAHs	2.45E+01	3.04E+00	7.45E+01	0.432	1727.26	0.02	0.00001	2.7	1.38E-04	110	1.3E-06
Total HMW PAHs	1.24E-02	2.60E+00	3.21E-02	0.432	1727.26	0.02	0.00001	2.7	5.95E-08	3.07	1.9E-08
Volatile Organic Compounds (VOCs)											
Toluene	1.20E+00	7.24E+01	8.69E+01	0.432	1727.26	0.02	0.00001	2.7	1.61E-04	74.3	2.2E-06

Notes:
AOC = Area of Concern
AUF = Area Use Factor (AOC area/Home Range); all areas are given in acres.
BAF = Bioaccumulation factor. BAFs identified in Table A-1 and literature from Sample, 1996 and EPA, 2007b.
BW = Body Weight.
Dose = [(Concentration in mice) x (FIR)/Body Weight] x (AUF).
HMW = High Molecular Weight. Polynuclear Aromatic Hydrocarbons (PAHs) HQ calculated as total low and high molecular weight PAHs as a result of insufficient NOAELs and LOAELs for individual compounds in accordance with USEPA protocols (EPA, 2007a).
HQ = Hazard Quotient (Dose/LOAEL).
kg - kilograms
kg/day - kilograms per day
LMW = Low Molecular Weight
LOAEL = Lowest Observed Adverse Effect Level (Sample, 1996)
mg/kg = milligrams per kilogram
N = Nutrient
NA = Not Available
NC = Not Calculated
(1) Exposure Point Concentration = maximum detected concentration.
(2) Predicted small mammal concentration (EPC x BAF)
(3) FIR = Food Ingestion Rate. The food ingestion rates of the red fox range from 0.069 g/g BW/day for a nonbreeding adult, to 0.16 g/g BW/day for a juvenile (U.S. EPA 1993).
To express this value in units of g/day, the highest reported food ingestion rate of 0.16 g/g BW/day was multiplied by
the lowest reported body weight of 2.7 kg (2,700 g) to yield a food ingestion rate of 432 g/day.
(4) HR = Home Range, the average recorded mean home range of 699 hectares (EPA, 1993; Sargeant, 1972) was used in the AUF calculation.
(5) Adult red fox weigh from 2.7 to 7 kg (Barbour and Davis 1974; Jones and Birney 1988).

Source for BAF and LOAEL

EPA. 2007a. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Final OSWER Directive 9285.7-78. June 2007
EPA. 2007b. Attachment 4-1 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs OSWER Directive 9285.7-55. Issued November 2003, Revised February 2005, Revised April 2007.
Sample, B.E., D.M. Opresko, and G.W. Suter, II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. June 1996

Table A-6
Hazard Quotient Calculations for the Red-tailed Hawk (LOAEL)
Sludge
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia

Contaminant	Exposure Point Concentration (1) (mg/kg)	BAF	Predicted Small Mammal Concentration (2) (mg/kg)	FIR (3) (kg/day)	HR (4) (acres)	AOC (acres)	AUF	Body Weight (5) (kg)	Dose (mg/kg BW/day)	LOAEL (mg/kg BW/day)	HQ
Metals											
Aluminum, Total	6.90E+03	8.44E-03	5.83E+01	0.113	148.3	0.02	0.000134898	1.028	8.64E-04	44.5	1.9E-05
Antimony, Total	2.00E+01	4.80E-02	9.60E-01	0.113	148.3	0.02	0.000134898	1.028	1.42E-05	NA	NC
Cadmium, Total	3.70E+00	5.87E-01	2.17E+00	0.113	148.3	0.02	0.000134898	1.028	3.22E-05	20	1.6E-06
Chromium, Total	6.50E+01	1.00E+00	6.50E+01	0.113	148.3	0.02	0.000134898	1.028	9.65E-04	5	1.9E-04
Copper, Total	1.80E+02	7.97E-02	1.43E+01	0.113	148.3	0.02	0.000134898	1.028	2.13E-04	61.7	3.4E-06
Iron, Total	1.50E+04	1.81E-02	2.71E+02	0.113	148.3	0.02	0.000134898	1.028	4.02E-03	NA	NC
Lead, Total	5.30E+02	3.18E-02	1.69E+01	0.113	148.3	0.02	0.000134898	1.028	2.50E-04	11.3	2.2E-05
Manganese, Total	2.70E+02	1.52E-02	4.09E+00	0.113	148.3	0.02	0.000134898	1.028	6.07E-05	997	6.1E-08
Mercury, Total	2.80E+01	1.45E+00	4.07E+01	0.113	148.3	0.02	0.000134898	1.028	6.04E-04	0.064	9.4E-03
Silver, Total	1.30E+02	2.24E-02	2.91E+00	0.113	148.3	0.02	0.000134898	1.028	4.32E-05	NA	NC
Vanadium, Total	1.80E+01	1.67E-02	3.01E-01	0.113	148.3	0.02	0.000134898	1.028	4.47E-06	11.4	3.9E-07
Zinc, Total	6.80E+02	2.43E-01	1.65E+02	0.113	148.3	0.02	0.000134898	1.028	2.45E-03	131	1.9E-05
Pesticides											
4,4'-DDD	1.20E+00	1.00E+00	1.20E+00	0.113	148.3	0.02	0.000134898	1.028	1.78E-05	0.028	6.4E-04
4,4'-DDE	1.40E+00	2.40E+00	3.36E+00	0.113	148.3	0.02	0.000134898	1.028	4.99E-05	0.028	1.8E-03
4,4'-DDT	1.10E+00	1.50E-01	1.65E-01	0.113	148.3	0.02	0.000134898	1.028	2.45E-06	0.028	8.7E-05
Dieldrin	9.90E-03	1.00E+00	9.90E-03	0.113	148.3	0.02	0.000134898	1.028	1.47E-07	0.077	1.9E-06
Polynuclear Aromatic Hydrocarbons (PAHs)											
Total LMW PAHs	2.45E+01	3.04E+00	7.45E+01	0.113	148.3	0.02	0.000134898	1.028	1.11E-03	1653	6.7E-07
Total HMW PAHs	1.24E-02	2.60E+00	3.21E-02	0.113	148.3	0.02	0.000134898	1.028	4.77E-07	20	2.4E-08
Volatile Organic Comounds (VOCs)											
Toluene	1.20E+00	7.24E+01	8.69E+01	0.113	148.3	0.02	0.000134898	1.028	1.29E-03	NA	NC

Notes:
AOC = Area of Concern
AUF = Area Use Factor (AOC area/Home Range), all areas are given in acres.
BAF = Bioaccumulation factor. BAFs identified in Table A-1, and literature from Sample, 1996, and EPA, 2007b.
BW = Body Weight.
Dose = [(Concentration in mice) x (FIR)/Body Weight] x (AUF).
HMW = High Molecular Weight
HQ = Hazard Quotient (Dose/LOAEL). Polynuclear Aromatic Hydrocarbons (PAHs) HQ calculated as total low and high molecular weight PAHs as a result of insufficient NOAELs and LOAELs for individual compounds in accordance with EPA protocols (EPA, 2007a).
kg - kilograms
kg/day - kilograms per day
LMW = Low Molecular Weight
LOAEL = Lowest Observed Adverse Effect Level (Sample, 1996).
mg/kg = milligrams per kilogram
N = Nutrient
NA = Not Available
NC = Not Calculated
(1) Exposure Point Concentration = maximum detected concentration.
(2) = Predicted small mammal concentration (EPC x BAF)
(3) FIR = Food Ingestion Rate. The food ingestion rates of the red-tailed hawk range from 0.086 g/g BW/day for an adult male in summer, to 0.11 g/g BW/day for an adult female in winter (EPA, 1993).
To express this value in units of g/day, the highest reported food ingestion rate of 0.11 g/g BW/day was multiplied by
the lowest reported body weight from the same study of 1.028 kg to yield a food ingestion rate of 0.113 kg/day.
(4) HR = Home Ranges vary from 148.26 to 395.36 acres (Kirkwood, 1980); the smallest home range of 148.36 acres was used in the AUF calculation.
(5) Adult male red-tailed hawks from the midwest weigh an average of 1.028 kg (Craighead and Craighead, 1956).

Source for BAF and LOAEL
EPA. 2007a. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Final OSWER Directive 9285.7-78. June 2007
EPA. 2007b. Attachment 4-1 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs OSWER Directive 9285.7-55. Issued November 2003, Revised February 2005, Revised April 2007.
Sample, B.E., D.M. Opresko, and G.W. Suter, II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. June 1996

Table A-7
Hazard Quotient Calculations for the American Robin (LOAEL)
Sludge
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia

Contaminant	Exposure Point Concentration [1] (mg/kg)	BAF	Predicted Small Mammal Concentration [2] (mg/kg)	FIR [3] (kg/day)	HR [4] (acres)	AOC (acres)	AUF	Body Weight [5] (kg)	Dose (mg/kg BW/day)	LOAEL (mg/kg BW/day)	HQ
Metals											
Aluminum, Total	6.90E+03	8.44E-03	5.83E+01	0.117	0.37	0.02	0.05405	0.077	4.77E+00	44.5	1.1E-01
Antimony, Total	2.00E+01	4.80E-02	9.60E-01	0.117	0.37	0.02	0.05405	0.077	7.85E-02	NA	NC
Cadmium, Total	3.70E+00	5.87E-01	2.17E+00	0.117	0.37	0.02	0.05405	0.077	1.78E-01	20	8.9E-03
Chromium, Total	6.50E+01	1.00E+00	6.50E+01	0.117	0.37	0.02	0.05405	0.077	5.32E+00	5	1.1E+00
Copper, Total	1.80E+02	7.97E-02	1.43E+01	0.117	0.37	0.02	0.05405	0.077	1.17E+00	61.7	1.9E-02
Iron, Total	1.50E+04	1.81E-02	2.71E+02	0.117	0.37	0.02	0.05405	0.077	2.22E+01	NA	NC
Lead, Total	5.30E+02	3.18E-02	1.69E+01	0.117	0.37	0.02	0.05405	0.077	1.38E+00	11.3	1.2E-01
Manganese, Total	2.70E+02	1.52E-02	4.09E+00	0.117	0.37	0.02	0.05405	0.077	3.35E-01	997	3.4E-04
Mercury, Total	2.80E+01	1.45E+00	4.07E+01	0.117	0.37	0.02	0.05405	0.077	3.33E+00	0.064	5.2E+01
Silver, Total	1.30E+02	2.24E-02	2.91E+00	0.117	0.37	0.02	0.05405	0.077	2.38E-01	NA	NC
Vanadium, Total	1.80E+01	1.67E-02	3.01E-01	0.117	0.37	0.02	0.05405	0.077	2.46E-02	114	2.2E-04
Zinc, Total	6.80E+02	2.43E-01	1.65E+02	0.117	0.37	0.02	0.05405	0.077	1.35E+01	131	1.0E-01
Pesticides											
4,4'-DDD	1.20E+00	1.00E+00	1.20E+00	0.117	0.37	0.02	0.05405	0.077	9.82E-02	0.028	3.5E+00
4,4'-DDE	1.40E+00	2.40E+00	3.36E+00	0.117	0.37	0.02	0.05405	0.077	2.75E-01	0.028	9.8E+00
4,4'-DDT	1.10E+00	1.50E-01	1.65E-01	0.117	0.37	0.02	0.05405	0.077	1.35E-02	0.028	4.8E-01
Dieldrin	9.90E-03	1.00E+00	9.90E-03	0.117	0.37	0.02	0.05405	0.077	8.10E-04	0.077	1.1E-02
Polynuclear Aromatic Hydrocarbons (PAHs)											
Total LMW PAHs	2.45E+01	3.04E+00	7.45E+01	0.117	0.37	0.02	0.05405	0.077	6.10E+00	1653	3.7E-03
Total HMW PAHs	1.24E-02	2.60E+00	3.21E-02	0.117	0.37	0.02	0.05405	0.077	2.63E-03	20	1.3E-04
Volatile Organic Comounds (VOCs)											
Toluene	1.20E+03	7.24E+01	8.69E+04	0.117	0.37	0.02	0.05405	0.077	7.11E+03	NA	NC

Notes:

Shading - indicates hazard quotients greater than 1.

AOC = Area of Concern

AUF = Area Use Factor (AOC area/Home Range), all areas are given in acres.

BAF = Bioaccumulation factor. BAFs identified in Table A-1, and literature from Sample, 1996, and EPA, 2007b.

BW = Body Weight.

Dose = [(Concentration in mice) x (FIR)/Body Weight] x (AUF).

HMW = High Molecular Weight. Polynuclear Aromatic Hydrocarbons (PAHs) HQ calculated as total low and high molecular weight PAHs as a result of insufficient NOAELs and LOAELs for individual compounds in accordance with USEPA protocols (USEPA, 2007a).

HQ = Hazard Quotient (Dose/LOAEL).

kg - kilograms

kg/day - kilograms per day

LMW = Low Molecular Weight

LOAEL = Lowest Observed Adverse Effect Level (Sample, 1996).

mg/kg = milligrams per kilogram

N = Nutrient

NA = Not Available

NC = Not Calculated

PRG = Preliminary Remediation Goal

(1) Exposure Point Concentration = maximum detected concentration.

(2) Predicted small mammal concentration (EPC x BAF)

(3) FIR = Food Ingestion Rate. The food ingestion rates of the American robin range from 0.89 g/g BW/day for a breeding juvenile in the west, to 1.52 g/g BW/day for breeding juvenile in the Midwest (USEPA, 1993).
To express this value in units of g/day, the highest reported food ingestion rate of 1.52 g/g BW/day was multiplied by
the lowest reported body weight from the same study of 0.0773 kg to yield a food ingestion rate of 0.117 kg/day.

(4) HR = Home Range, the low end median recorded home range of 0.15 hectares (USEPA, 1993; Weatherhead & McRae, 1990) was used in the AUF calculation.

(5) All season adult American Robins from the east weigh an average of 0.0773 kg (Clench & Leberman, 1978).

Source for BAF and LOAEL

EPA. 2007a. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Final OSWER Directive 9285.7-78. June 2007
EPA. 2007b. Attachment 4-1 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs OSWER Directive 9285.7-55. Issued November 2003, Revised February 2005, Revised April 2007.
Sample, B.E., D.M. Opresko, and G.W. Suter, II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. June 1996

Table A-8
Hazard Quotient Calculations for the Short-tailed Shrew (LOAEL)
Sludge
Former Wastewater Treatment Plant
Wallops Flight Facility, Virginia

Contaminant	Exposure Point Concentration [1] (mg/kg)	BAF	Predicted Small Mammal Concentration [2] (mg/kg)	FIR [3] (kg/day)	HR [4] (acres)	AOC (acres)	AUF	Body Weight [5] (kg)	Dose (mg/kg BW/day)	LOAEL (mg/kg BW/day)	HQ
Metals											
Aluminum, Total	6.90E+03	8.44E-03	5.83E+01	0.011	0.96	0.02	0.02083	0.017	7.67E-01	22.952	3.3E-02
Antimony, Total	2.00E+01	4.80E-02	9.60E-01	0.011	0.96	0.02	0.02083	0.017	1.26E-02	1.487	8.5E-03
Cadmium, Total	3.70E+00	5.87E-01	2.17E+00	0.011	0.96	0.02	0.02083	0.017	2.86E-02	21.2	1.3E-03
Chromium, Total	6.50E+01	1.00E+00	6.50E+01	0.011	0.96	0.02	0.02083	0.017	8.56E-01	58.88	1.5E-02
Copper, Total	1.80E+02	7.97E-02	1.43E+01	0.011	0.96	0.02	0.02083	0.017	1.89E-01	40	4.7E-03
Iron, Total	1.50E+04	1.81E-02	2.71E+02	0.011	0.96	0.02	0.02083	0.017	3.57E+00	NA	NC
Lead, Total	5.30E+02	3.18E-02	1.69E+01	0.011	0.96	0.02	0.02083	0.017	2.22E-01	175.83	1.3E-03
Manganese, Total	2.70E+02	1.52E-02	4.09E+00	0.011	0.96	0.02	0.02083	0.017	5.39E-02	624	8.6E-05
Mercury, Total	2.80E+01	1.45E+00	4.07E+01	0.011	0.96	0.02	0.02083	0.017	5.36E-01	0.352	1.5E+00
Silver, Total	1.30E+02	2.24E-02	2.91E+00	0.011	0.96	0.02	0.02083	0.017	3.84E-02	NA	NC
Vanadium, Total	1.80E+01	1.67E-02	3.01E-01	0.011	0.96	0.02	0.02083	0.017	3.97E-03	4.285	9.3E-04
Zinc, Total	6.80E+02	2.43E-01	1.65E+02	0.011	0.96	0.02	0.02083	0.017	2.18E+00	703.3	3.1E-03
Pesticides											
4,4'-DDD	1.20E+00	1.00E+00	1.20E+00	0.011	0.96	0.02	0.02083	0.017	1.58E-02	8.79	1.8E-03
4,4'-DDE	1.40E+00	2.40E+00	3.36E+00	0.011	0.96	0.02	0.02083	0.017	4.43E-02	8.79	5.0E-03
4,4'-DDT	1.10E+00	1.50E-01	1.65E-01	0.011	0.96	0.02	0.02083	0.017	2.17E-03	8.79	2.5E-04
Dieldrin	9.90E-03	1.00E+00	9.90E-03	0.011	0.96	0.02	0.02083	0.017	1.30E-04	0.44	3.0E-04
Polynuclear Aromatic Hydrocarbons (PAHs)											
Total LMW PAHs	2.45E+01	3.04E+00	7.45E+01	0.011	0.96	0.02	0.02083	0.017	9.82E-01	110	8.9E-03
Total HMW PAHs	1.24E-02	2.60E+00	3.21E-02	0.011	0.96	0.02	0.02083	0.017	4.23E-04	3.07	1.4E-04
Volatile Organic Compounds (VOCs)											
Toluene	1.20E+00	7.24E+01	8.69E+01	0.011	0.96	0.02	0.02083	0.017	1.14E+00	309.2	3.7E-03

Notes:

Shading - indicates hazard quotients greater than 1.

AOC = Area of Concern

AUF = Area Use Factor (AOC area/Home Range), all areas are given in acres.

BAF = Bioaccumulation factor. BAFs identified in Table A-1, and literature from Sample, 1996, and USEPA, 2007b.

BW = Body Weight.

Dose = [(Concentration in mice) x (FIR)/Body Weight] x (AUF).

HMW = High Molecular Weight. Polynuclear Aromatic Hydrocarbons (PAHs) HQ calculated as total low and high molecular weight PAHs as a result of insufficient NOAELs and LOAELs for individual compounds in accordance with USEPA protocols (USEPA, 2007a).

HQ = Hazard Quotient (Dose/LOAEL).

kg - kilogram

kg/day - kilograms per day

LMW = Low Molecular Weight

LOAEL = Lowest Observed Adverse Effect Level (Sample, 1996).

mg/kg = milligrams per kilogram

N = Nutrient

NA = Not Available

NC = Not Calculated

PRG = Preliminary Remediation Goal

(1) Exposure Point Concentration = maximum detected concentration.

(2) Predicted small mammal concentration (EPC x BAF)

(3) FIR = Food Ingestion Rate. The highest food ingestion rates of the short-tailed shrew range documented are 0.62 g/g BW/day (USEPA, 1993).
To express this value in units of g/day, the highest reported food ingestion rate of 0.62 g/g BW/day was multiplied by
the lowest reported body weight from the same study of 0.017 kg to yield a food ingestion rate of 0.011 kg/day.

(4) HR = Home Range, median recorded home range of 0.39 hectares (0.96 acres) (USEPA, 1993) was used in the AUF calculation.

(5) Mean summer female short-tailed shrew weight is 17.40 g (0.0174 kg) (USEPA, 1993).

Source for BAF and LOAEL

EPA. 2007a. Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs) Interim Final OSWER Directive 9285.7-78. June 2007

EPA. 2007b. Attachment 4-1 Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs) Exposure Factors and Bioaccumulation Models for Derivation of Wildlife Eco-SSLs OSWER Directive 9285.7-55. Issued November 2003, Revised February 2005, Revised April 2007.

Sample, B.E., D.M. Opresko, and G.W. Suter, II. 1996. Toxicological Benchmarks for Wildlife: 1996 Revision. June 1996

APPENDIX B

COST ESTIMATES

TABLE B-1

SUMMARY OF COST ESTIMATES
REMEDIAL ACTION ALTERNATIVES
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Alternative No.	Backup Information	Estimated Costs		
		Capital	First Annual O&M	Present Net Worth
Alternative 1 - No Action	None Required	$0	$0	$0
Alternative 2 - Land Use Controls	Tables B-2, B-3, and B-4	$117,000	$50,000	$365,000
Alternative 3 - Low-Permeability Cap Installation	Tables B-5, B-6, and B-7	$305,000	$44,000	$563,000
Alternative 4 - Sludge Removal and Off-Site Disposal	Tables B-8 and B-9	$316,000	$0	$316,000

TABLE B-2

CAPITAL COSTS
ALTERNATIVE 2 - LAND USE CONTROLS
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Process	Unit Cost	Quantity	Unit of Measure	Subtotal	Description
Land Use Restrictions					
LUC Remedial Design	$10,000	1	LS	$10,000	90 hours x $100/hour + expenses.
Master Plan Revisions/Deed Restriction	$20,000	1	LS	$20,000	Wallops Flight Facility Master Plan Revisions and deed restrictions through Accomack County. 150 hrs x $100/hour + expens
Signage (purchase and install)	$400	6	EA	$2,400	Purchase and placement of 6 signs along the chain-link (mesh) fence. $200 purchase + $200 install per sign.
Brochures/Fact Sheets/Print Media	$5,000	1	LS	$5,000	Preparation and distribution of brochures/fact sheets/newspaper ads.
Information Packages to Agencies	$5,000	1	LS	$5,000	Preparation and distribution of info packages.
Access Restrictions					
Work Plan/APP Preparation	$12,000	1	LS	$12,000	100 hours x $100/hour + expenses.
Brush Clearing	$4,000	0.25	ACRE	$1,000	Vegetation removal in the area for the fence installation which equates to approx. 0.25 acre.
Fence Installation	$20	160	FT	$3,200	Purchase and installation of chain-link (mesh) fencing, gate, and avian netting.
Environmental Monitoring (Year 1)					
LTM Plan/APP Preparation	$12,000	1	LS	$12,000	100 hours x $100/hour + expenses.
Planning/Mobilization/Demobilization	$100	24	HR	$2,400	8 hours of planning and 16 hours of mobilization/demobilization for two personnel.
Sludge Sampling	$80	30	HR	$2,400	Assumes two engineers and one SSHO for one 10-hr day with collection of 10 samples
Sludge Sample Analysis	$250	10	EA	$2,500	Analysis of sludge samples for Pesticides ($150/sample) and metals ($100/sample)
Sampling Equipment/Supplies	$500	1	DAY	$500	Equipment (hand auger) and supplies (decon and scoops/bowls) needed for sludge sampling.
Data Validation	$50	10	EA	$500	Data validation of sludge samples.
Data Evaluation	$80	10	HR	$800	Evaluation of analytical data
Report Preparation	$100	40	HR	$4,000	40 hours x $100/hour + expenses.

Notes:	Subtotal :	$83,700
EA - Each		
FT - Feet	Subtotal :	$83,700
HR - Hour	gineering and Administration (20%):	$16,740
LS - Lump sum	Contingency (20%):	$16,740
	TOTAL :	**$117,000**

TABLE B-3

O&M COSTS (EVERY 5 YEARS)
ALTERNATIVE 2 - LAND USE CONTROLS
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Process	Unit Cost	Quantity	Unit of Measure	Subtotal	Description
Land Use Restrictions Update					
Deed Restriction (verification update)	$2,500	1	LS	$2,500	Verify deed restrictions through the Accomack County. 20 hrs x $100/hour + expenses.
Signage Inspection	$100	4	HR	$400	4 hours x $100/hour. Time includes travel time to site
Brochures/Fact Sheets/Print Media	$2,000	1	LS	$2,000	Preparation and distribution of brochures/fact sheets/newspaper ads.
Information Packages to Agencies	$5,000	1	LS	$5,000	Preparation and distribution of info packages.
Access Restrictions					
Fence Inspection	$100	4	HR	$400	Inspection of chain-link fencing, 4 hours x $100/hour. Time includes travel time to site
Fence and Signage Repairs	$1,000	1	LS	$1,000	Repair fence and signage.
Environmental Monitoring					
LTM Plan/APP Update	$3,500	1	LS	$3,500	30 hours x $100/hour + expenses
Planning/Mobilization/Demobilization	$100	24	HR	$2,400	8 hours of planning and 16 hours of mobilization/demobilization for two personnel.
Sludge Sampling	$80	30	HR	$2,400	Assumes two engineers and one SSHO for one 10-hr day with collection of 10 samples
Sludge Sample Analysis	$250	10	EA	$2,500	Analysis of sludge samples for Pesticides ($150/sample) and metals ($100/sample)
Sampling Equipment/Supplies	$500	1	DAY	$500	Equipment (hand auger) and supplies (decon and scoops/bowls) needed for sludge sampling.
Data Validation	$50	10	EA	$500	Data validation of sludge samples.
Data Evaluation	$80	10	HR	$800	Evaluation of analytical data
Report Preparation	$100	40	HR	$4,000	40 hours x $100/hour + expenses.
Five-Year Review					
Report Preparation	$100	80	HR	$8,000	80 hours x $100/hour + expenses.

Subtotal :	$35,900
Subtotal :	$35,900
Engineering and Administration (20%):	$7,180
Contingency (20%):	$7,180
TOTAL :	**$50,000**

Notes:
EA - Each
HR - Hour
LS - Lump sum

TABLE B-4

PRESENT NET WORTH CALCULATIONS
ALTERNATIVE 2 - LAND USE CONTROLS
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Year	Capital Cost	O&M Costs	Total	Present Worth Discount Factor	Present Net Worth
1	$117,000	$0	$117,000	1.0	$117,000
2	$0	$0	$0	0.99	$0
3	$0	$0	$0	0.98	$0
4	$0	$0	$0	0.97	$0
5	$0	$0	$0	0.96	$0
6	$0	$50,000	$50,000	0.95	$47,310
7	$0	$0	$0	0.94	$0
8	$0	$0	$0	0.93	$0
9	$0	$0	$0	0.92	$0
10	$0	$0	$0	0.91	$0
11	$0	$50,000	$50,000	0.90	$44,764
12	$0	$0	$0	0.89	$0
13	$0	$0	$0	0.88	$0
14	$0	$0	$0	0.87	$0
15	$0	$0	$0	0.86	$0
16	$0	$50,000	$50,000	0.85	$42,356
17	$0	$0	$0	0.84	$0
18	$0	$0	$0	0.83	$0
19	$0	$0	$0	0.82	$0
20	$0	$0	$0	0.81	$0
21	$0	$50,000	$50,000	0.80	$40,077
22	$0	$0	$0	0.79	$0
23	$0	$0	$0	0.78	$0
24	$0	$0	$0	0.78	$0
25	$0	$0	$0	0.77	$0
26	$0	$50,000	$50,000	0.76	$37,921
27	$0	$0	$0	0.75	$0
28	$0	$0	$0	0.74	$0
29	$0	$0	$0	0.73	$0
30	$0	$0	$0	0.73	$0
31	$0	$50,000	$50,000	0.72	$35,881

Total: $365,000

Notes:
31-year period of performance selected instead of 30 years because capital costs are reflected as year 1 on this table.

TABLE B-5

CAPITAL COSTS
ALTERNATIVE 3 - LOW-PERMEABILITY CAP INSTALLATION
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Process	Unit Cost	Quantity	Unit of Measure	Subtotal	Description
Land Use Restrictions					
LUC Remedial Design	$10,000	1	LS	$10,000	90 hours x $100/hour + expenses.
Master Plan Revisions/Deed Restriction	$20,000	1	LS	$20,000	Wallops Flight Facility Master Plan Revisions and deed restrictions through Accomack County. 150 hrs x $100/hour + expenses.
Signage (purchase and install)	$400	8	EA	$3,200	Purchase and placement of 8 signs along the chain-link fence. $200 purchase + $200 install per sign.
Brochures/Fact Sheets/Print Media	$5,000	1	LS	$5,000	Preparation and distribution of brochures/fact sheets/newspaper ads.
Information Packages to Agencies	$5,000	1	LS	$5,000	Preparation and distribution of info packages.
Planning Documents					
Work Plan Preparation	$15,000	1	LS	$15,000	120 hours x $100/hour + expenses.
APP/SSHP Preparation	$12,000	1	LS	$12,000	100 hours x $100/hour + expenses.
Erosion Control Plan Preparation	$5,000	1	LS	$5,000	45 hours x $100/hour + expenses.
Site Preparation					
Brush Clearing	$4,000	1	ACRE	$4,000	Vegetation removal in the area of the soil cover installation and any access roads = approx. 1 acre
Installation of erosion controls (silt fence)	$2	300	LF	$600	Installation of silt fencing around the site and around former Wastewater Treatment Plant
Installation of access roads	$10,000	1	LS	$10,000	Costs include heavy equipment, labor, and stone.
Dust suppression with Water Truck	$500	1	WK	$500	Costs only include water truck rental (labor costs included in cover placement).
Low-Permeability Cap Installation					
Import Clay	$25	1,210	TON	$30,250	Clean-fill (clay) + delivery costs about $20/cubic yard or $25/ton. Volume estimated at 0.25 acres area x 2 ft depth = 21,780 cubic ft = 807 cubic yards = 1,210 tons (1.5 tons/cubic yard factor used).
Geotextile Liner	$168	1	10x60 roll	$168	6oz geotextile underlayment costs about $168 for a 10x60 roll
Low-Permeability Clay Cap Placement and Grading	$27,600	1	WK	$27,600	Costs include $6,000 per week for equipment and $21,600 for personnel (labor and per diem). Personnel will include site superintendent, 3 equipment operators, 1 SSHO, and 4 laborers.
Surveying Support for Final Grade	$1,000	1	DAY	$1,000	Survey costs equal $1000 per for two-man team and effort is estimated at one day.
Site Restoration					
Vegetate Cover	$5,000	0.5	ACRE	$2,500	Costs include $5,000 per acre for seed and labor.
Access Road Restoration	$10,000	1	LS	$10,000	Costs include estimated heavy equipment use, labor, and disposal of any stone.
Remedial Action Report					
Report	$50,000	1	LS	$50,000	450 hours x $100/hour + expenses.

Subtotal :	$178,618
Mobilization/Demobilization (10%):	$17,862
Subtotal :	$196,480
dial Contractor Profit and Overhead (15%):	$29,472
Engineering and Administration (20%):	$39,296
Contingency (20%):	$39,296
TOTAL :	**$305,000**

Notes:
EA - Each
LF - Linear foot
LS - Lump sum
WK - Week

TABLE B-6

O&M COSTS
ALTERNATIVE 3 - LOW-PERMEABILITY CAP INSTALLATION
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Process	Unit Cost	Quantity	Unit of Measure	Subtotal	Description
Land Use Restrictions Update (every 5 years)					
Deed Restriction (verification update)	$2,500	1	LS	$2,500	Verify deed restrictions through Accomack County. 20 hrs x $100/hour + expenses.
Signage Inspection	$100	4	HR	$400	4 hours x $100/hour.
Brochures/Fact Sheets/Print Media	$2,000	1	LS	$2,000	Preparation and distribution of brochures/fact sheets/newspaper ads.
Information Packages to Agencies	$5,000	1	LS	$5,000	Preparation and distribution of info packages.
Low-Permeability Cap Inspection and Maintenance (annually for first 3 years after remedial action complete, every five years thereafter)					
Inspection	$100	8	HR	$800	Inspection of soil cover, 8 hours x $100/hour
Cover Maintenance/Sign Repairs	$10,000	1	LS	$10,000	Soil and vegetative cover maintenance estimate and sign repairs.
Inspection Report	$2,500	1	LS	$2,500	20 hours x $100/hour + expenses.
Five-Year Review					
Report Preparation	$100	80	HR	$8,000	80 hours x $100/hour + expenses.

Subtotal :	$31,200
Subtotal :	$31,200
Engineering and Administration (20%):	$6,240
Contingency (20%):	$6,240
TOTAL :	**$44,000**

Notes:
HR - Hour
LS - Lump sum

TABLE B-7

PRESENT NET WORTH CALCULATIONS
ALTERNATIVE 3 - LOW-PERMEABILITY CAP INSTALLATION
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Year	Capital Cost	O&M Costs	Total	Present Worth Discount Factor	Present Net Worth
1	$305,000	$13,300	$318,300	1.0	$318,300
2	$0	$13,300	$13,300	0.99	$13,154
3	$0	$13,300	$13,300	0.98	$13,009
4	$0	$0	$0	0.97	$0
5	$0	$0	$0	0.96	$0
6	$0	$44,000	$44,000	0.95	$41,633
7	$0	$0	$0	0.94	$0
8	$0	$0	$0	0.93	$0
9	$0	$0	$0	0.92	$0
10	$0	$0	$0	0.91	$0
11	$0	$44,000	$44,000	0.90	$39,393
12	$0	$0	$0	0.89	$0
13	$0	$0	$0	0.88	$0
14	$0	$0	$0	0.87	$0
15	$0	$0	$0	0.86	$0
16	$0	$44,000	$44,000	0.85	$37,273
17	$0	$0	$0	0.84	$0
18	$0	$0	$0	0.83	$0
19	$0	$0	$0	0.82	$0
20	$0	$0	$0	0.81	$0
21	$0	$44,000	$44,000	0.80	$35,268
22	$0	$0	$0	0.79	$0
23	$0	$0	$0	0.78	$0
24	$0	$0	$0	0.78	$0
25	$0	$0	$0	0.77	$0
26	$0	$44,000	$44,000	0.76	$33,370
27	$0	$0	$0	0.75	$0
28	$0	$0	$0	0.74	$0
29	$0	$0	$0	0.73	$0
30	$0	$0	$0	0.73	$0
31	$0	$44,000	$44,000	0.72	$31,575

Total: $563,000

Notes:
31-year period of performance selected instead of 30 years because capital costs are reflected as year 1 on this table.
PNW is based on a 1.1% average annual rate of inflation over 21 years.

TABLE B-8

CAPITAL COSTS
ALTERNATIVE 4 - SLUDGE REMOVAL AND OFF-SITE DISPOSAL
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Process	Unit Cost	Quantity	Unit of Measure	Subtotal	Description
Planning Documents					
Work Plan Preparation	$15,000	1	LS	$15,000	125 hours x $100/hour + expenses.
APP/SSHP Preparation	$12,000	1	LS	$12,000	100 hours x $100/hour + expenses.
Erosion Control Plan Preparation	$5,000	1	LS	$5,000	45 hours x $100/hour + expenses.
Site Preparation					
Brush Clearing	$4,000	1	ACRE	$4,000	Vegetation removal in the area of the soil cover installation and any access roads = approx. 1 acre
Installation of erosion controls (silt fence)	$2	300	LF	$600	Installation of silt fencing around the site and around former Wastewater Treatment Plant
Installation of access roads	$10,000	1	LS	$10,000	Costs include heavy equipment, labor, and stone.
Dust suppression with Water Truck	$500	1	WK	$500	Costs only include water truck rental (labor costs included in cover placement).
Sludge Sampling for Off-Site Disposal					
Sludge Sampling For Off-Site Disposal Requirements	$80	30	HR	$2,400	Assumes two engineers and one SSHO for one 10-hr day with collection of 8 samples
Sludge Sample Analysis	$545	2	EA	$1,090	Analysis of (2) sludge samples for landfill requirements ($545 total for each sample). Pesticides ($150 per sample), TPH-DRO ($110 per sample), EOX-total extractable organic halides ($80 per sample), BTEX ($70 per sample), and TCLP metals ($135 per sample)
Sludge Excavation					
Excavate Sludge from Drying Beds	$27,600	1	WK	$27,600	Costs include $6,000 per week for equipment and $21,600 for personnel (labor and per diem). Personnel will include site superintendent, 3 equipment operators, 1 SSHO, and 4 laborers. Volume estimated at 66 CY for both sludge drying beds. 66 CY x 1.3 tons/CY = 85.8 tons.
Vacuum Sludge from Settling Tanks	$15,000	1	WK	$15,000	Costs include $5,000 per day for equipment and $10,000 for personnel (labor and per diem). Personnel will include site superintendent, equipment operator, and SSHO. Volume of sludge in the settling tanks estimated at 16.5 CY (16.5 CY x 1.3 tons/CY = 21.45 tons.
Surveying Support for Final Grade	$1,000	1	DAY	$1,000	Survey costs equal $1000 per for two-man team and effort is estimated at one day.
Off-Site Transportation and Disposal					
Off-Site Transportation	$8	107.25	TON	$858	Costs include $8 per ton for transport of sludge to landfill.
RCRA Subtitle D Landfill Disposal	$30	107.25	TON	$3,218	Costs include $30 per ton for disposal in Subtitle D landfill.
Confirmation Sampling and Analysis					
Work Plan/APP Preparation	$12,000	1	LS	$12,000	100 hours x $100/hour + expenses
Planning/Mobilization/Demobilization	$100	24	HR	$2,400	8 hours of planning and 16 hours of mobilization/demobilization for two personnel.
Sludge Sampling	$80	30	HR	$2,400	Assumes two engineers and one SSHO for one 10-hr day with collection of 8 samples
Sludge Sample Analysis	$250	8	EA	$2,000	Analysis of sludge samples for Pesticides ($150/sample) and metals ($100/sample)
Sampling Equipment/Supplies	$500	1	DAY	$500	Equipment (hand auger) and supplies (decon and scoops/bowls) needed for sludge sampling.
Data Validation	$50	8	EA	$400	Data validation of sludge samples.
Data Evaluation	$80	8	HR	$640	Evaluation of analytical data
Report Preparation	$100	40	HR	$4,000	35 hours x $100/hour + expenses.
Site Restoration					
Excavation Areas Re-grading	$10,000	1	WK	$10,000	Costs include front end loader and labor
Vegetate Cover	$5,000	0.5	ACRE	$2,500	Costs include $5,000 per acre for seed and labor.
Access Road Restoration	$10,000	1	LS	$10,000	Costs include estimated heavy equipment use, labor, and disposal of any stone.
Remedial Action Report					
Report	$40,000	1	LS	$40,000	300 hours x $100/hour + expenses. Includes inspection event to document vegetative restoration.

Subtotal :	$185,106
Mobilization/Demobilization (10%):	$18,511
Subtotal :	$203,616
Remedial Contractor Profit and Overhead (15%):	$30,542
Engineering and Administration (20%):	$40,723
Contingency (20%):	$40,723
TOTAL :	**$316,000**

Notes:
EA - Each
LF- Linear foot
LS - Lump sum
HR - Hour
WK - Week

TABLE B-9

PRESENT NET WORTH CALCULATIONS
ALTERNATIVE 4 - SLUDGE REMOVAL AND OFF-SITE DISPOSAL
FORMER WASTEWATER TREATMENT PLANT
WALLOPS FLIGHT FACILITY, WALLOPS ISLAND, VA

Year	Capital Cost	O&M Costs	Total	Present Worth Discount Factor	Present Net Worth
1	$316,000	$0	$316,000	1.0	$316,000
2	$0	$0	$0	0.99	$0
3	$0	$0	$0	0.98	$0
4	$0	$0	$0	0.97	$0
5	$0	$0	$0	0.96	$0
6	$0	$0	$0	0.95	$0
7	$0	$0	$0	0.94	$0
8	$0	$0	$0	0.93	$0
9	$0	$0	$0	0.92	$0
10	$0	$0	$0	0.91	$0
11	$0	$0	$0	0.90	$0
12	$0	$0	$0	0.89	$0
13	$0	$0	$0	0.88	$0
14	$0	$0	$0	0.87	$0
15	$0	$0	$0	0.86	$0
16	$0	$0	$0	0.85	$0
17	$0	$0	$0	0.84	$0
18	$0	$0	$0	0.83	$0
19	$0	$0	$0	0.82	$0
20	$0	$0	$0	0.81	$0
21	$0	$0	$0	0.80	$0
22	$0	$0	$0	0.79	$0
23	$0	$0	$0	0.78	$0
24	$0	$0	$0	0.78	$0
25	$0	$0	$0	0.77	$0
26	$0	$0	$0	0.76	$0
27	$0	$0	$0	0.75	$0
28	$0	$0	$0	0.74	$0
29	$0	$0	$0	0.73	$0
30	$0	$0	$0	0.73	$0
31	$0	$0	$0	0.72	$0

Total: $316,000

Notes:
31-year period of performance selected instead of 30 years because capital costs are reflected as year 1 on this table.
PNW is based on a 1.1% average annual rate of inflation over 21 years.